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CURRENT SOIL PROCESSES IN THE SOUTHERN FOREST ZONE

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A KNOWLEDGE of current soil-forming processes is necessary for an understanding of soil genesis, as well as for working out rational systems of soil management. In studying these processes, great significance is placed on the investigation of soil solutions. These, together with soil air, are the most dynamic parts of the soil. The fundamental processes of transforming soil constituents, such as the disintegration of the mineral particles, the decomposition of organic residues and the synthesis of organomineral compounds, take place in the soil solutions or by their direct participation. The products of soil formation and weathering move through the soil profile in dissolved form. Eminent Russian and foreign scientists attach great significance to the investigation of soil solutions (3, 4, 6, 20, 12 and others). Nevertheless, until the last decade the study of soil solutions was made difficult by the lack of reliable methods for separating the solution from the solid phase. Consequently, investigators resorted to indirect methods: the investigation of aqueous extracts, ground water and lysimeter water.

The study of water extracts from podzolic soils gave investigators some notion of the relation between the elements in their liquid phase. They could sometimes reproduce experimentally the processes taking place in the soil (10, 12). In preparing the aqueous extracts, however, it is impossible to avoid dissolving too much of the slightly soluble compounds. Hydrolytic and oxidizing processes do not give a true idea of the soil solutions composition, or of their alterations in the course of time. Considerably more reliable data on the composition of natural soil solutions are obtained by investigating lysimetric and grounds waters. But it is only possible to obtain them at a moisture equal to or close to the full moisture-holding capacity.

The problem of obtaining unaltered soil solutions was solved in the post-war years by the work of Kryukov (11) and Komarova (8), who proposed a series of methods based on the application of pressure and the displacement of the solution by means of ethyl alcohol. From 1945 to 1950 we used these methods to study the dynamics of the composition of soil solutions from a number of localities in the Moscow region. From July, 1945, until May, 1947, the studies were conducted on a tract near the Rumyantsev station of the Kalinin railroad line. We investigated solutions of peat-podzolic clay loam soils under coniferous forest and grassy vegetation, and also of peaty-podzolic-gley soils under mossy plant cover. After July, 1947, the work was transferred to the Podushkinsk forestry tract (23 km. west of Moscow). Here we investigated solutions from peat-intensively podzolized soils under oak forest and intensively podzolized soils under a forest of spruce and wood-sorrel. From 1949 to 1950 we studied the dynamics of the chemical composition of soil solutions from cultivated peat-podzolic soils of the collective farm "Kolos," Dmitrovsk section, Moscow region.

Peat-podzolic soils like those we investigated are widely distributed in the southern part of the forest zone. All the peat-podzolic soils investigated are morphologically very similar. They vary mainly in the character of their litter and, in part, of their A_1 horizons. Characteristic of these soils is the great thickness of their A_2 horizons (15 to 20 cm.), their whitish pale-yellow color, the considerable podzolization of the humus-accumulative horizon and of the upper part of the illuvial horizon. The absence of signs of gleying throughout the whole thickness of the soil is also characteristic. In the soils studied, the water table is deep (none was found in the Podushkinsk tract after boring to a depth of 7.9 meters).

The thickness of the litter of peat-podzolic soils in the vicinity of Moscow varies sharply during the year. In the oak forest the litter usually disappears toward July. In the spruce forest it appreciably decreases in thickness and the upper part of the A_1 horizon becomes darker.

Marked seasonal changes in the organic matter content and the relation of these changes to

TABLE 1

Some chemical properties of soils of the Rumyantsev and Podushkinsk experimental tracts
(Analysis by A. F. Shcherbakov)

Profile No.	Name of soil	Genetic horizon	Depth of sample, cm.	pH		Adsorbed cations, meq.				Total cations, meq.	Unsaturation, %	Humus, % (Tyurin)	Fraction less than 0.001, %
				Water extract	Salt extract	Ca	Mg	H	Al				
1	Peat-intensively podzolized (spruce forest, Rumyantsev)	A_1	5–10	5.45	Not det'd.	1.10	0.61	0.065	1.30	3.07	44	2.81	12.3
		A_2	10–16	6.08	"	6.75	0.57	0.026	0.00	1.34	2	0.22	9.9
		B	60–70	4.83	"	8.85	4.61	0.026	5.04	18.82	27	0.28	29.8
3	Peat-intensively podzolized (glade, Rumyantsev)	A_1	6–12	5.97	"	1.00	0.32	0.059	0.54	1.91	31	1.24	13.8
		A_2	19–24	6.49	"	0.85	0.54	0.063	0.20	1.65	16	0.30	8.5
		B	50–60	5.44	"	8.25	4.70	0.046	1.89	14.88	13	0.30	30.5
		C	115–120	5.87	"								
4	Peat-intensively podzolized (oak forest, Podushkinsk)	A_1	0–6	6.24	5.58	4.75	2.06	None[a]		6.81	None	3.37	13.5
		$A_1 + A_2$	6–16	5.22	5.21	2.15	1.15	1.40		4.70	30	1.23	13.1
		A_2	16–22	5.40	4.80	2.00	1.07	2.62		5.69	46	0.45	10.6
		A_2B	32–40	4.84	4.07	4.65	2.30	3.80		9.28	39	0.22	20.8
		"	50–60	4.81	4.38	7.45	3.61	5.50		16.56	33	Not det'd.	30.4
		B	80–88	4.68	3.95	8.15	4.03	5.80		18.48	31	"	32.6
		C	100–110	4.78		9.55	5.09			14.64		"	33.4
5	Intensively podzolized (spruce, wood-sorrel forest, Podushkinsk)	A_1	2–10	4.53	3.98	3.45	1.57	6.00		11.02	54	3.59	13.8
		"	10–20	5.19	4.40	2.30	1.07	3.00		7.61	39	1.58	12.1
		A_2	20–36	5.39	4.83	2.40	1.23	2.60		6.23	42	0.33	7.8
		A_2B	36–50	4.90	4.00	7.55	3.78	2.70		14.03	19	9.26	28.8
		"	50–60	5.04	Not det'd.	7.95	3.86	2.80		14.60	19	0.22	27.8
		B_1	70–80	4.92	"	10.40	5.67	1.70		17.71	10	Not det'd.	31.1
		B_2	100–110	5.16	"	11.70	7.07	None		17.77	None	"	32.4

[a] In profiles 4 and 5 the sum of adsorbed H and Al was determined by the Gedroits method.

the character of the plant debris and to weather conditions are shown by our own visual observations on the rate at which litter decomposes. These are also shown by the data of Abramova (1) for the Central Forest Reservation and of Smirnova (16) for the Zvenigorodsk Biological Station on the dynamics of the humus content in peat-podzolic soils. These data correspond directly to Kononova's (9) statement regarding the rapid decomposition of plant residues in the southern peat-podzolic zone. Also we studied the data of Rybalkina (14) on the microorganism content during the summer months in the tracts.

Data from determining the texture of peat-podzolized soils indicate that the upper horizons show the accumulation (so common to podzolic soils) of the coarse silt fraction[1] at the expense of their clay fractions. However, unlike typical podzolic soils, within the upper 30 cm., the content of the fraction smaller than 0.001 mm. is lowest in the podzolic horizon. The humus-accumulative horizon contains from 1.5 to 2.0 times as many clay particles as the podzolic horizon (Table 1).

The accumulation of the clay fraction correlates well with the data from total analysis of the soils. Yet the character of the vegetation is superimposed on this accumulation. Thus, in the soils of the Podushkinsk forestry tract under oak forest, in addition to some decrease in the silica content, there is an accumulation of Ca, K, Na, S, Ti and Mn in the humus-accumulative horizon and of phosphorus in the highest part of the humus horizon. Less intensive accumulation takes place in the humus-accumulative horizon of soils under spruce forest. Such elements as K, Na, Mn and Ti accumulate here in smaller amounts than in soils under oak forest, but Ca and P are intensively leached out. The relative accumulation of the clay fractions undoubtedly has a biological character.

Current vegetation exerts a very strong influence on the distribution of exchange acidity in the soil (Table 1). Thus, in an intensively podzolized soil under spruce-wood sorrel, the exchange acidity attains a maximum value in the humus horizon (6 meq.). This maximum coincides with the maximal unsaturation in the soil. The exchange acidity sharply decreases with depth. A completely reversed picture is observed in soil under oak forest. In the upper part of the humus horizon there is no exchange acidity. It appears only at a depth of 6 cm. Acidity rapidly increases downward, and attains its maximum value in the illuvial horizon. Under the present climate in the oak forest with deep root system and vegetative debris rich in calcium, the conditions are not realized for the formation of acid, base-unsaturated decomposition products of organic residues. However, the presence of considerable unsaturation in the illuvial horizon results from vital activities of the oak root system (13) and from microbiological processes embracing the deep soil horizons and creating weathering *in situ* (5).

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[1] From 0.01 mm. to 0.05 mm.—Translator.

The solutions were to be displaced from soil samples taken monthly (except in winter) from June, 1945, to May, 1947, in the Rumyantsev tract and from June, 1947, to November, 1948, in the Podushkinsk tract. Level areas were selected for taking the samples. The samples were preserved in glass jars at a temperature between +2° and +3° C. It was established experimentally that the composition of the solutions change negligibly at such a temperature.

The separation of the solution from the solid soil phase was done with the aid of the Kryukov apparatus (11) and an oil press. The solution was displaced from 300 to 400 grams of soil at pressures varying from 25 to 50 kilograms per $cm.^2$, with a maximum of 100. After the flow of solution ceased, the remaining free moisture was displaced from the soil with alcohol. Displacement was continued until the appearance of the first drop of alcohol. By applying such pressure, we pressed out the so-called "free solution," that is, the solution contained in the capillaries and in the pores in and between the aggregates. The use of alcohol permitted the supplementary displacement of a large part of the moisture from the fine pores within the aggregates. We called this "residual" moisture. By comparing its quantity from samples taken at different periods it was shown that "residual" moisture is a dynamic quantity varying regularly during the year.

Figure 1 shows the variation of natural and "residual" moisture in soils of the Rumyantsev and the Podushkinsk tracts during the investigations. Moisture determinations were made in samples taken monthly for extraction of the soil solution under pressure. The data we obtained do not contradict conclusions reached by Vasil'ev (2) who made a detailed study in 1948 and 1949 of moisture relations in soils of the Podushkinsk tract under spruce and oak forest and under plowed fields. The fundamental conclusion is that while the moisture content in the upper horizons is extremely dynamic, the moisture of the podzolic and especially of the illuvial horizons is distinctively uniform. At present the summer rains seldom penetrate deeper than 10 cm. in the Moscow region forest plantings in peat-podzolized soils with clay loam. Such rains are almost completely lost through evaporation and transpiration. There is a more or less thorough soaking of the soils during the short intervals between the fall decreased transpiration and freezing, and between the spring thaw and initial transpiration.

We obtained interesting data on residual moisture relations. Residual moisture was always most abundant in spring and late fall. During the summer, and sometimes in the early fall months, we observed a sharp decrease in the "residual" moisture content. The greatest fluctuation in the "residual" moisture took place in the litter. Its content sometimes changed twentyfold. Its content in the illuvial horizons varied very slightly. The podzolic horizon contained the smallest amount of "residual" moisture. A characteristic fact is that after the summer of 1946, with weather conditions favorable for the development of biochemical processes, the amount of "residual" moisture in horizons $A_0 + A_1$ of a glade soil and in the peat horizon of a peaty-podzolic gley soil increased sharply, while in all other horizons of the three soils studied we noted a marked decrease in this form of moisture.

Trofimov (18) was the first to establish the seasonal change of the soil's bound water content. He judged the content by the amount of negative adsorption of the electrolytes. He explained the decrease in bound moisture during the summer by the variation in concentration of the free soil solution. This resulted from the drying of the soils and the accompanying transformation of a part of the bound moisture to the free state. In our view, the cause of the

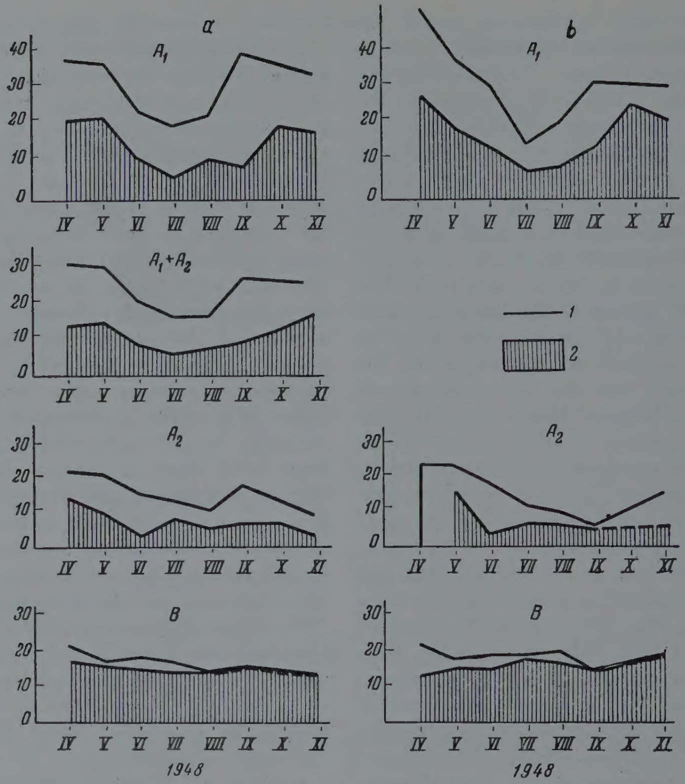

FIG. 1.—Dynamics of natural and residual moistures in soils of the Podushkinsk forest tract. a—Peat-intensively podzolized soil under oak forest; b—intensively podzolized soil under spruce forest; 1—moisture as percent of dry soil; 2—residual moisture as percent of dry soil.

variations in the "residual" soil moisture is also *seasonal variation in the amount and composition of the organic matter and, to a lesser degree, of the mineral soil colloids*. Besides the investigations on the seasonal variation in the amount of soil humus, to which we have already referred, a series of publications have recently appeared on the occurrence of seasonal change in the composition of soil colloids (17, 19, 7 and others), on the increase in their dispersion during the spring and late fall and decrease during the summer. These publications confirm our assumptions. The marked variability of the "residual" soil moisture must exert an influence on the conditions for plant nutrition and, in our view, deserves special study.

In order to characterize the soil solutions, samples were taken from each section three to five times. We wanted to judge whether the differences in local origin had an influence on the determinations of changes in composition and concentration of the solutions in the course of time. We therefore conducted a mathematical analysis of the results from three periods of observations on three components of the solution (soluble organic matter, total acidity and Ca) in peat-intensively podzolized soils of the Podushkinsk tract. The mathematical analysis indicated that the seasonal change we found in concentration and composition was completely reliable (15).

In the soil solutions isolated from the solid phase we determined pH, electrical conductance, content of soluble organic matter, calcium, NH_3, silicic acid, iron and chloride. To determine these elements, existing electrochemical and micro-

TABLE 2

Variability in the composition of soil solutions from soils of the Podushkinsk forest tract during the period of investigations

(from June, 1947, to November, 1948)[a]

Profile No.	Name of soil	Depth in cm.	pH	Total alkalinity (in meq. HCO_3)	Acidity in meq. H per liter		Dissolved organic matter mg./l.	Electrical conductance in mhos × 10^{-5}	In meq./l. of solution			
					Total	From CO_2			Ca	NH_3	SiO_2	FE_2O_3
4	Intensively podzolized (spruce forest)	A_0 0–3	4.5–6.4	1.6–3.7	1.2–24.4	0.0–2.2	1480–11098	40–1597	3.7–15.1	2–7.8	0.9–1.7	0.1–2.9
		A_1 5–10	4.9–6.3	0.12–0.6	0.6–2.9	0.0–1.3	90–784	43–179	1.5–9.4	0.1–7.3	0.3–1.0	0.0–0.7
		A_2 20–55	5.2–7.1	0.06–0.3	0.2–1.0	0.0–0.5	20–597	35.5–131.2	1.5–6.8	0.1–3.2	0.1–0.4	0.0–0.3
		B 50–60	5.8–7.3	0.03–0.4	0.1–1.0	0.0–0.4	0.0–150.2	31.2–36.3	1.0–3.1	0.1–2	0.2–0.5	0.0–0.1
5	Peat intensively podzolized (oak forest)	A_0 0–2	4.9–5.3	4.3–6.2	5.0–19.3	1.5–4.6	3137–8533	64.8–2629	4.3–17.0	2.3–13.9	0.8–1.1	1.3–2.5
		A_1 2–6	5.9–7.3	0.2–1.5	0.3–4.3	0.0–4.0	140–764	23.2–48.9	1.1–3.6	0.1–2.1	0.2–0.5	0.0–0.2
		$A_1 + A_2$ 6–12	6–7.1	0.2–1.0	0.2–1.3	0.0–1.2	88–349	8.8–32	0.5–3.6	0.04–1.4	0.1–0.5	0.0–0.2
		A_2 15–20	5.7–6.9	0.1–0.7	0.2–0.6	0.0–0.6	42–232	14.1–30.3	0.5–1.6	0.04–0.97	0.04–0.3	0.0–0.1
		B 50–60	6.3–7.6	0.1–0.6	0.2–0.4	0.0–0.08	0.0–0.08		0.3–4.0	0.0–0.8	0.2–0.4	0.0–0.04

[a] At the lower concentration of the solutions of the upper horizons of soils from the Rumyantsev tract, the pattern of change in solutions in the soil profile is the same as in soils of the Podushkinsk forest tract (15).

chemical methods were used. The acid-base equilibrium of the solutions was determined by potentiometric titration.

In Table 2 we present the limits of variability in the composition of the soil solutions during the period of investigations for each soil horizon of the soils studied. The table shows primarily that the composition and concentration of the components vary sharply along the profile. The differences in composition and concentration of the soil solutions isolated from the humus and podzolic horizons of the same soil are significantly greater than such differences among soil solutions from the same horizons of all soils studied.

Soluble organic matter predominates in the composition of the solutions from forest litter. Its concentration may attain 8 to 11 grams per liter of solution. The solutions from litter have a high electrical conductance (to 265 × 10^{-5} mhos), a high content of nonvolatile organic acids (coniferous litter) and their salts (deciduous litter). The reaction of the solutions from coniferous litter is acid (pH 4.4 to 6.4). There is much calcium in the solutions from litter, (9 to 16 milliequivalents per liter) and also ammonia (6 to 13 milliequivalents per liter). There is a relatively high iron content (2 to 3 milliequivalents per liter). The litter solutions have a brown color.

In solutions from the humus horizons of all the soils studied, the concentration of organic matter (maximum 0.5 to 0.7 grams per liter) is significantly lower than in solutions from litter. There is a marked decrease in electrical conductance. Their content of Ca, SiO_2 and NH_3 is considerably lower. The iron content falls very sharply (0.2 to 0.7 milliequivalents per liter). The solutions have light-yellow and greenish tones. Yet, in their composition and in the concentration of their components, solutions from the humus-accumulative horizons are closer to solutions from litter than to soil solutions from the podzolic and illuvial horizons. In all the soils studied from Moscow district and at all periods of the year solutions from the podzolic and illuvial horizons are colorless, transparent and have a very low concentration. Their electrical conductance is low (especially in solutions from the podzolic and illuvial horizons of soils under oak forest and grassy vegetation). Their content of Ca, SiO_2 and NH_3 decreases sharply. They have a negligible content of organic matter (0 to 0.30 grams per liter) and of Fe_2O_3 (0.0 to 0.1 milliequivalents per liter). The pH is slightly acid, close to neutral or even slightly alkaline.

In addition to this, the character of the present day plant cover and soil-forming process leaves a deep impression on the composition and concentration of the soil solutions from the upper soil horizons, and especially on the seasonal variations in the concentration of the solutions.

Before passing on to the characteristics of such concentrations, let us describe the weather conditions during the period under study. Four of the years—1945, 1947, 1949 and 1950—during which our experiments were conducted, were marked by a cold, wet growing period. Two of the years—1946 and 1948—were characterized by a fairly wet, hot summer, and were exceptionally favorable for the development of biological and particularly of biochemical processes.

Figure 2 represents the titration curves of the soil solutions by means of which we were able to gain an understanding of the acid alkaline equilibrium of the solutions. The curves were obtained as follows: to a definite part of the soil solution, after determining its pH, a definite amount of 0.01 N HCl was added from a burette, with stirring by means of a current of CO_2-free air to eliminate the volatile reaction products (CO_2, NH_3). When equilibrium was attained, the pH was measured, and again the same amount of 0.01 N HCl was added. The operation was repeated until the solution reached pH 3. The same solution was then titrated with alkali until it reached pH 9.

The data obtained were plotted graphically. The pH values were plotted along the vertical axis. To the left of the central line is the amount of milliliters of HCl required to titrate 1 liter of soil solution; to the right of the point corresponding to pH 3, the amount of milliliters of NaOH. When CO_2 and bicarbonates were absent from the soil solution, the curves of the direct titration with acid and the back titration with alkali to the equivalence point coincided.

Figure 2 *a* represents the curves of the potentiometric titration of coniferous litter and horizons A_1, A_2 and B of peat-intensively podzolized soils under dead spruce litter of the Rumyantsev district. The initial reaction of the coniferous litter was acid. The titration curves were marked by pronounced buffering both in the acid and in the alkaline flat-portion of the curve. This indicates the presence of salts of weak organic acids in the solutions. The reaction of the solutions and their buffering action markedly varied in the course of time. The lowest reaction and the greatest buffering action were shown by the litter solutions in July, 1946, a period which was marked by the most favorable conditions for biochemical processes. As a rule, carbonic acid and bicarbonates were absent from the solutions. From this it is evident that the *soluble products from the decomposition of coniferous litter, under the hydrothermal conditions of the Moscow zone, are mainly nonvolatile free organic acids and their salts. The concentration and "strength" of these acids also increase in proportion to the improvement in the conditions under which this decomposition takes place and to the intensification of the degree of decomposition.*

We have already pointed out that with profile depth the concentration of the solutions sharply decreased and their composition changed. The titration curves show this condition graphically. The buffering of the solutions had already decreased considerably in horizon A_1, but in horizons A_2 and B the titration curves approached that for distilled water. Nonvolatile organic acids completely disappeared from the solutions, while a small amount of free carbon dioxide appeared.

A different composition of the solutions and a different pattern of changes in the course of time were shown by litter solutions from peat-podzolic soils under grassy vegetation (Fig. 2, *b*). The reaction of the solutions was slightly alkaline (June to July, 1946) or slightly acid. In this last case the acidity of the solutions was due to carbonic acid (the pH increased abruptly when CO_2-free air was bubbled through the solutions). The considerable buffering in the acid part of the flat curve during the summer of 1946 was due to the presence of bicarbonates of strong bases (calcium), as shown by the divergence between the curves for the direct and the back titrations. Buffering in the alkaline part of the flat curve during this period was also high, but it appeared at a pH of 8 to 10 in the solutions. It was linked to the presence of ammonium salts of nonvolatile organic acids. We determined by direct analysis the high concentrations of Ca and NH_3 in the solutions during June and July of 1946. It follows that *the soluble decomposition products of the top residues from grassy vegetation are the final decomposition products (H_2O, CO_2), soluble salts of nonvolatile organic acids and bicarbonates of strong bases.*

Thus, an improvement in the conditions for the decomposition of the top portion of vegetative residues leads to diametrically opposite results in coniferous forest and in glades. In conif-

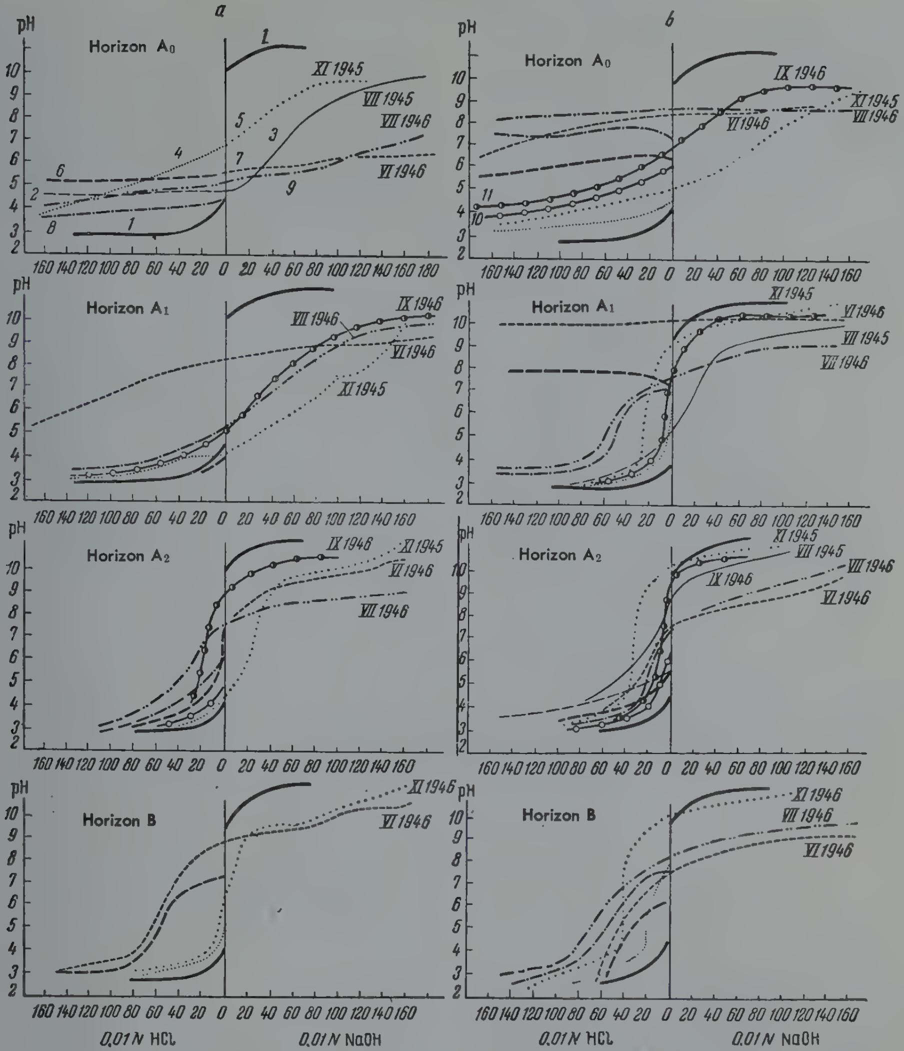

FIG. 2.—Titration curves of soil solutions from peat-intensively podzolized soils of the Rumyantsev tract under various kinds of vegetation (in ml. of 0.01 N acid or alkali per liter of solution). a—Under spruce forest; b—under grassy vegetation. 1—Curve of distilled water; 2—curve of the direct titration with 0.01 N HCl, July, 1945; 3—curve of the back titration with 0.01 N NaOH, July, 1945; 4—curve of direct titration with 0.01 N HCl, November, 1945; 5—curve of back titration with 0.01 N NaOH, November, 1945; 6—curve of direct titration with 0.01 N HCl, June, 1946; 7—curve of back titration with 0.01 N NaOH, June, 1946; 8—curve of direct titration with 0.01 N HCl, July, 1946; 9—curve of back titration with 0.01 N NaOH, July, 1946; 10—curve of direct titration with 0.01 N HCl, September, 1946; 11—curve of back titration with 0.01 N NaOH, September, 1946.

(Designations of the curves are given under a, Horizon A_0)

erous forest the solutions turn acid as a result of an intensified intake of nonvolatile organic acids. In glades there is alkalinization at the expense of an intensified intake of salts of strong bases and of weak organic acids. Peaty litters behave like coniferous ones. Titration curves of solutions from horizons A_2 and B of glade soil and of peaty-podzolic-gley soil are very similar to curves for soils under spruce forest. These solutions have negligible buffering and contain small amounts of free carbon dioxide and calcium bicarbonate.

Thus, the analysis of the potentiometric titration curves confirms the occurrence of a wide change in the composition and concentration of soil solutions from all soils of the Rumyantsev tract as the solutions move from the litter down into the soil depths.

Figure 3, *a* and *b*, represents the dynamics of the mineral and organic elements in soil solutions from the Podushkinsk tract. Here, in place of titration curves, the titratable alkalinity and acidity were determined by the usual methods (titration with acid and alkali). The nature of

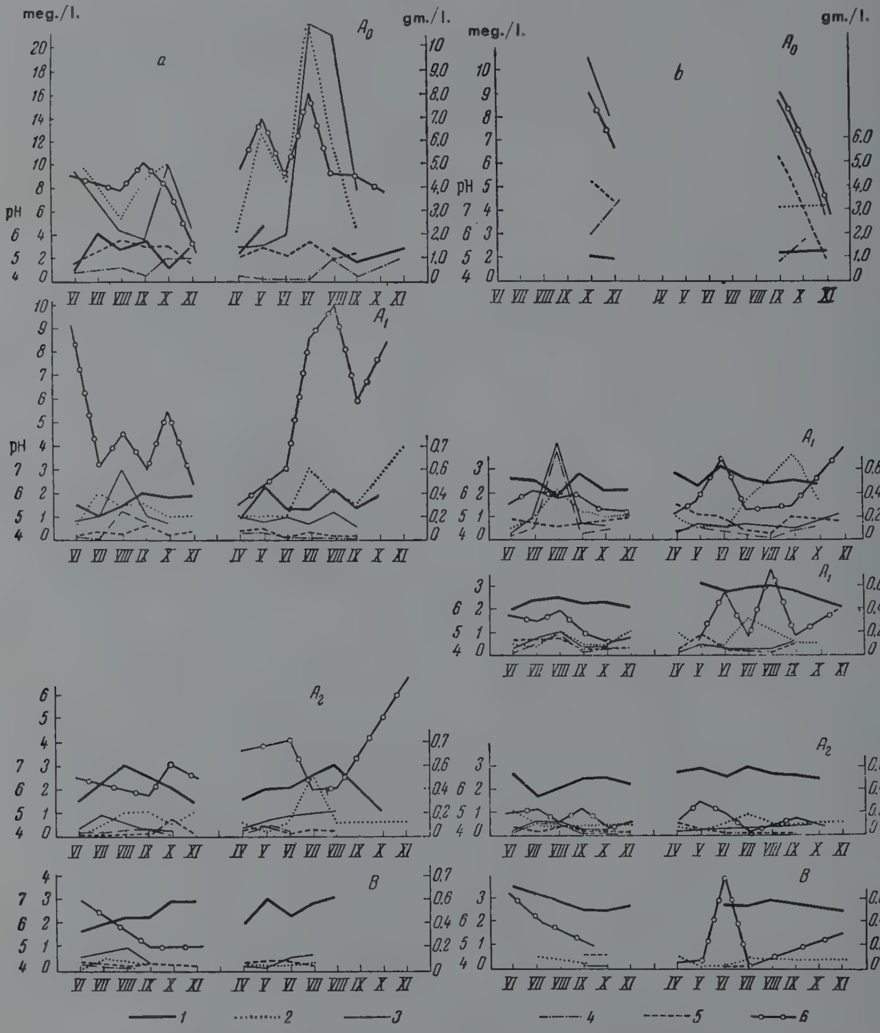

FIG. 3.—Dynamics of the chemical composition of soil solutions from soils of the Podushkinsk forest tract. a—Intensively podzolized soil under spruce forest; b—peat-intensively podzolized soil under oak forest. 1—pH; 2) organic matter, grams per liter; 3—total acidity, milliequivalents per liter; 4—CO_2 acidity in milliequivalents per liter; 5—total alkalinity in milliequivalents per liter; 6—calcium in milliequivalents per liter.

the change in the course of time of the composition and concentration of solutions from the Podushkinsk section was also closely linked to the intensity and the direction of the biochemical processes and the nature of the plant cover.

During the cold, rainy summer of 1947, the concentration of solutions from coniferous litter was relatively low, but it increased somewhat towards August, the driest month. During the hot, wet summer of 1948, the concentration of solutions from the litter sharply increased and became 1.5 to 2.0 times as high as in 1947. During this period, there was an abrupt increase in the concentration of organic matter and of acidity in the solution, the acidity was due essentially (as in Rumyantsev) to nonvolatile organic acids. The total alkalinity was negligible.

In passing from the litter to the lower horizons, the concentration of mineral and organic substances decreased, but less abruptly than in the other soils. The concentration of mineral elements in horizon A_1 (judging by the electrical conductance and the Ca content) rose abruptly in July and reached its maximum value in August. In horizon A_2, the maximum concentration of the solutions was observed in November. Thus, infiltration of solutions from the upper horizons under spruce influences the formation of solutions in the lower horizons. The Ca and NH_3 were combined chiefly with nonvolatile organic acids.

A difference is observed in soils under oak forest. Here, in horizons A_1, A_2 and B, the concentration of the solutions is somewhat lower, but the trend of the change is the same in all horizons. The concentration of the solutions attained its maximum value in June, 1948. This is because in soils under oak forest the main factor determining the composition of the solutions is not the infiltration of solutions downwards from above, but decomposition processes which are common to the whole profile, such as the decomposition of root debris from grassy and woody vegetation, and of litter which is usually dragged into horizon A_1 by earthworms.

The reaction of the solutions was slightly acidic in cold and rainy periods and neutral in warm and dry ones. During the wet, cold summer of 1947, both the acidity of the solutions and also their organic matter content increased towards August. The acidity was due entirely to carbon dioxide, evidently associated with hindrance to the diffusion into the air of the carbon dioxide formed in root respiration and in microbiological processes under conditions of excessive moisture in the upper soil horizons. Quite a different picture was observed in 1948, with its hot, fairly wet summer. The total acidity of the solutions was very small, and the carbon dioxide disappeared completely. The concentration of the soil solutions in horizons A_2 and B under oak forest was small. They contained an especially small amount of organic matter. Moreover, the concentration of Ca and NH_3, which was low in 1947, sharply increased in the summer of 1948. Iron was usually absent in the solutions from these horizons. Thus, an improvement in the conditions favoring decomposition in soils under oak forest leads to intensified mineralization of the organic residues throughout the whole soil profile, to alkalinization of the solutions and to their enrichment in organic and mineral salts of Ca and NH_3. Fixation of the decomposition products of organic residues in horizons A_1 and A_2 was unusually pronounced.

On the basis of the facts presented, we reached the following conclusions:

1) In peat-podzolic, intensively podzolized and peaty-podzolic-gley soils of the Moscow region, biochemical processes are a fundamental factor in the formation of the organic and mineral parts of the soil solutions.

2) The intensity of the biochemical processes decreases from the litter to the humus-accumulative horizon and then to the podzolic and illuvial horizons.

3) The chemical composition and the concentration of the soil solutions from the upper soil horizons vary widely in the course of time. The composition of solutions from horizons A_2 and B is significantly more constant yet it is seldom possible to obtain free soil solutions from the latter, since all the moisture in this horizon is in the bound state during a large part of the year.

4) The character of the plant cover exerts a deep influence on the composition and the concentration of organic and mineral substances in the soil solutions. The biochemical processess taking place in the litter are of great importance for the composition of solutions from podzolic soils under coniferous forest and from peaty-podzolic-gley soils under mossy plant cover. The main products of biochemical decomposition which find their way into the soil solution are nonvolatile organic acids and their salts. The

more intensively the decomposition proceeds, the more acidic and concentrated the solutions from horizons A_0 and A_1 become. Some increase in the concentration of soil solutions from horizons A_2 and B is linked to the infiltration into these soils of moisture from upper horizons.

5) The products of the biochemical decomposition of litter from peat intensively-podzolized soil under grassy vegetation (glades) and under oak forest are calcium and ammonium salts of organic acids, calcium bicarbonate and free carbon dioxide. The more favorable the conditions for decomposition, the greater the amount of these products passes into the soil solution, which turns alkaline. When the diffusion of carbon dioxide into the air becomes difficult (owing to excessive moisture in the upper horizon), the carbon dioxide remains in the soil solution and acidifies it.

6) In the soils of the Moscow area, under all types of vegetation, the solutions, as they move down deep into the profile, undergo marked changes: free organic acids (and, in part, their salts) are decomposed by microorganisms and are precipitated from the solution in horizon A_1; by absorbing organic matter from the solutions, iron and evidently also aluminum lose their mobility and are precipitated in horizon A_1. (Under Moscow area conditions the sesquioxides evidently migrate, mainly in the form of complex salts with organic matter). The concentration of the solutions in horizons A_2 and B abruptly decreases. A small amount of organic matter which reaches these horizons with the solutions is found here as ammonium and calcium salts. The Ca migrates here also in the form of bicarbonates. The solutions have a neutral and weak alkaline reaction. Soil solutions from the podzolic and illuvial horizons contain a negligible amount of iron or none at all.

To judge from the data that we have presented, those processes now taking place in soils with a clay loam in the southern part of the forest zone have little in common with the podzolization process. There is no doubt that the morphological appearance shown by the peat intensively-podzolized soils of the Moscow area, and the extreme paucity of clay fractions in their upper (30 cm.) soil stratum are the result of an intensive and prolonged podzolization process. Evidently this process began soon after the surface of the clay loam emerged from under glacial waters and continued under quite different physico-geographical conditions: a colder and more humid climate, less dissected topography and predominance of coniferous-mossy plant cover. Under present-day climatic conditions, with strongly dissected topography, under broadleaf-grassy forest, meadows and cultivated-lands, this process has already ceased and the signs of podzolization in the soil profiles are only those of a relict. To some extent, the podzolization process still goes on under coniferous forest with mossy cover. It is favored also by an intensive production of nonvolatile organic acids which easily percolate deep into the soil profile, and by conditions for periodic renewal. Against a background of general drainage, in dry summer periods along the borders of swamps, bog-soil processes frequently even alternate with podzolization. On disssected plains with peat intensively and medium podzolic soils with clay loam under broadleaf forests, meadows and plowlands, a unique peat-forming process is taking place at the present time. Its characteristic features are: an intensive biological cycle, a high ability of the soil humus to cause change, almost complete absence of the formation of nonvolatile free organic acids in the soil solution, and a significant change in the composition of the soil solution as the soil moisture percolates downwards. In the upper (10 cm.) soil stratum, where present processes take place at a faster rate, a secondary accumulation of clay occurs, but the lower (illuvial) horizon is subject to slow clay formation.

According to existing data, retardation of biochemical processes, more intensive downward movement and richer soil-forming minerals exist in the podzolic soils of the northern areas (Karelian Isthmus). Under these conditions, even in the summer months, there is intensified removal to the lower horizons of organic acids, sesquioxides and other mineral elements, and the present soil processes have distinct features of the podzolic type of soil formation.

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"SMOLNITSY" (SMONITSA) OF ALBANIA (CINNAMON-BROWN MEADOW AND MEADOW CINNAMON-BROWN DARK-COLORED MAGNESIUM SOLONETZ-LIKE SOILS)

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SMONITSA is a Serbian popular name for soils having a resinous-black color ("smonitsa" in the Serbian language means "resin"). The term was first introduced in the literature by Stebut (9), who devoted more than two decades to the study of these soils. Stebut considers that "smonitsy" soils belong to the hydromorphous series, associated with excessive moisture in southern latitudes. He considers that specific features of these soils are: a pronounced clay accumulation throughout the whole soil profile; the presence of special forms of organic matter which decompose with great difficulty and which impart a dark resinous color to the soil; and a variable composition of the adsorbed cations (Ca, Na, H). Depending on the degree of saturation with one or another cation, there is a sharp variation in those properties of the soil (water permeability, structure and others) which have a profound influence on productivity. Thus, according to Stebut, "smonitsy" may have either a high or a low productivity.

According to the data of Stebut (9, 10), the soils studied here are related to regions of mountain basins, which are widely distributed over the Balkan Peninsula. They have been formed on basic or ultrabasic rocks, or on their derivatives.

After Stebut, Serbian smolnitsy were discussed by Todorovich (11), Shtoker (14) and others. These soils have been described in Bulgaria (6 and others), where Antipov-Karatayev and Gerasimov (1) call them "chernozem-smolnitsy" In their opinion: "These soils are not unexpected intrazonal formations in the zone where the cinnamon-brown forest soils of Southern Bulgaria occur. The close relation of "chernozem-smolnitsy" to the cinnamon-brown soils is clearly brought out in two properties: 1) intensified clay formation and development of compact horizons, and 2) abundant production of carbonates of the alkaline-earth elements. Perhaps there is a third main property of the smolnitsy—their resin-black color—owing to that peculiar process of humus formation which is characteristic of cinnamon-brown soils; intensified decomposition of the mobile forms of organic matter and 'selective' accumulation of its more stable forms." According to these authors, the soils studied here are formed on andesites and on pliocene sediments, which also consist chiefly of decomposition products of andesites. They emphasize that the development of smolnitsy "is a regular phenomenon linked by entirely natural causes to the development zone of the cinnamon-brown soils. Their origin is not contradicted by the dry forest vegetation characteristic of this zone."

In his monograph "Soils of Europe," Kubiena (17) briefly considers the soils under study here, calls them "smonitsa," and classifies them under the hydromorphous series. In his opinion, these soils have an excess of moisture during winter and spring, but undergo dryness in the summer.

In Albania, the first to record the presence of "smonitsy" was Dalib Zavalani (21). Zavalani points out that similar soils of Macedonia, previously described by Stebut, are called smonitsy, and have been identified as chernozems. (In the first period of his studies on smonitsy, Stebut in fact refers to them as chernozems, but on closer acquaintance with them and, evidently as facts accumulated, he sharply changed his views and placed smonitsy soils under the hydromorphous series of soil formation). Zavalani as well as Stebut, relates them to the mountain basins.

In Albania, smolnitsy are found mainly in the eastern part of the mountain ridge section, where mountain basins abound. Mountain basins give the locality such a unique character, that Z. A. Mishunina (7) separated this section as an independent geographical region under the name of "zone of relative depressions." Fundamentally the region has been stratified on serpentines or on pyroxenes converted to serpentines.

As a rule, smolnitsy do not form any large continuous areas, but spread in small patches. These patches are mainly associated with the bottoms of basins, with depressions between the mountains and with all kinds of lake terraces. But they may also be found on slopes which are sometimes quite abrupt (up to 12° or more). In such cases the black horizon is less thick, seldom exceeding 50 cm., and often acquires a brownish hue.

The origin of these soils is linked to excessive moisture which in the one case is more or less constant (leveled surfaces, lake terraces) and in another has protracted periodicity (slopes, alluvial fans, and the like).

The region where smolnitsy find their maximum occurrence has a climate which is classified as continental Mediterranean, with a mean annual temperature of +9° to +12° C., and a total annual rainfall of 700 to 1000 mm.

We regret that we cannot say much about the natural vegetation of the soils described here, since all the plots of black soil that we saw were already tilled. It is true that the soil of profile 186 was covered with undergrowth of box (Buxus sempervirens). As regards the tilled areas, we may assume (considering their location within the zone of cinnamon-brown soils) that the vegetation of the smolnitsy is somewhat intermediate between the vegetation of the dry forests and the undergrowth and brushwood of the areas of excessive moisture.

Since the soils studied are found in the cinnamon-brown soils zone, we refer to them as belonging to the cinnamon-brown group. They are meadows, since their regime is hydromorphous. In order to emphasize their black coloration, we call them dark-colored. They have so much exchangeable magnesium (see below) that they are magnesium solonetz-like. Thus, the complete designation of the soils studied is as follows: cinnamon-brown meadow, dark-colored, magnesium solonetz-like (with excessive atmospheric and ground water) and meadow cinnamon-brown, dark-colored, magnesium solonetz-like (under excessive moisture from lateral flow of surface water).

A morphological description of the soils under study follows.

Cinnamon-Brown Meadow, Dark-Colored, Magnesium Solonetz-Like

Profile 240. Deposited near the Okhridsk lake on the first lake terrace, slightly inclined towards the lake (to the east). Plowed field.

A_p 0–20 cm.	Dark-brown fine-textured clay loam (when dried, black with light cinnamon-brown shades, firm cloddy structure). Fragments of parent rock are found. Sharp transition to the following horizon.
A′ 20–75 cm.	Black lumpy clay, sticky, tenaciously adheres to the spade. In air-dried condition, preserves its intensive black color. Firm cloddy structure. Glossy structural cross section, fragments of parent rock seldom found. Gradual transition to the underlying horizon.
A″ 75–110 cm.	Similar to the preceding, only with a somewhat paler color.
AB_f 110–120 cm.	Dark-brown fine-textured clay loam. Abundant gravel (somewhat rolled). Some fragments slightly effervesce. (The letter "f" indicates that the horizon is fragmentary; that is, that in this horizon the content of fine earth [particles <1 mm.] is less than 60% by weight.)

The quantitative proportion between the minerals in a cross section of the parent rock is as follows: serpentine 80%, bastite 10%, magnetite and spinel 10%. We have no reliable data on the fertility of these soils beyond information obtained from the peasants. According to their replies, the yield of corn and wheat per hectare varies between 10 and 15 and even goes up to 20 centners.

Meadow-Cinnamon Brown, Dark-Colored, Magnesium Solonetz-Like

These soils are found on slopes which are often quite abrupt, and their protracted periodic excessive moisture is related to surface water and, obviously, mainly to the lateral flow of water.

Here is a morphological description of a typical profile.

Profile 186. Along the road to Korcha (between El'basan and Libradzho). Altitude 3000 meters above sea level. Slope of 12° towards the southwest. Undergrowth of box. Clusters of common juniper are found. Very poor grass cover (grazed by cattle). Cattle paths. Outcrop of greenstone.

A_f 0–36 cm.	Dark cinnamon-brown clay. Clearly expressed medium blocky structure. When dried, it has the same color and a good medium granular structure. Roots of box. Angular small stones of parent rock. Transition fairly sharp.
AB_f 36–62 cm.	Black, cinnamon-brown glossy clay, extremely hard. Many small rootlets, coarse rock fragments are found. Comparatively gradual transition to the B horizon.
B_{1f} 62–80 cm.	The same clay, but with greenish tints. Many angular small stones. Plant roots notably fewer.
B_{2f} 80–100 cm.	Brown clay with faint dark tints. Many angular small stones. When dried to air-dry condition, the three lower horizons change neither their color nor their structure.

We present a microscopic analysis of a cross section of the soil forming parent material:

Profile 186. Pyroxene-peridotite converted to serpentine. Parent rock largely converted to serpentine. Serpentine essentially of the antigorite variety, which enclose small local residues of pyroxene. On the pyroxene patches, there is a secondary formation of coarse bastite. In its turn the bastite is replaced in places by antigorite. The parent rock is pierced by fine fissures, filled with magnetite ore in the form of broken chains.

The mineralogical composition, as determined in the cross section, was: pyroxene, 15%; serpentine, 70%; bastite, 10%; and magnetite 5%.

The "smolnitsy" of Albania, as indicated by morphological descriptions, are characterized by a very dark coloration extending to a considerable depth (in profile 240 down to 120 cm.; that is, practically to the bottom of the pit), fine texture, very coarse granular structure with glossy shine, especially in horizons A″ and AB.

Let us consider the analytical characteristics.

The particle-size data (Table 1) show that both the analyzed profiles are clay and have very high stickiness (to 56%). This, evidently, is one of the causes of their compactness and lumpiness. The middle part of the soil profile shows the highest clay content.

"Smolnitsy" of Albania characteristically have a neutral (from weakly acid to weakly alkaline) reaction. That is, their adsorbing complex is practically saturated by cations. Magnesium pre-

TABLE 1

Total analyses of cinnamon-brown meadow and meadow cinnamon-brown dark-colored magnesium solonetz-like soils

(Analyzed by Z. G. Il'kovskaya, A. N. Andreyeva, B. F. Mochalova, R. Yeremina, Z. Nikolayeva, Ye. A. Sinyagina)

Profile No.	Horizons	Depth, cm.	Loss on ignition, %	Hygroscopic water, %	pH (potentiometer)		Humus, % (Tyurin)	Nitrogen, % (Kjeldahl)	C:N	CO_2, % (Knopp)	Adsorbed cations (Godreits)[a]					Mg salinity, %	Particle size (mm. diameter), % (Kachinskiy)		Mobile compounds in mg./100 gm. of soil		
					Water extract	Saline extract					Ca	Mg	H	Ca:Mg	Ca + Mg		<0.001	<0.01	Fe^{++} (Kirsanov)	K (Peyva)	P_2O_5 (Machigin)
240	A	0–10	20.54	6.2	7.34	6.47	4.84	0.379	6.52	—	15.7	46.6	0.16	0.34	62.30	74.8	49	66	34.0	44.0	0.67
	A′	45–50	18.22	6.6	7.35	6.66	1.53	0.126	7.08	—	7.5	58.6	0.04	0.13	66.10	88.7	50	68	28.0	27.5	0.27
	A″	95–100	17.28	6.5	7.55	6.82	1.90	0.091	12.10	0.85	9.8[b]	57.4[b]	none	0.17	67.30	85.3	52	68	42.0	12.2	traces
	AB_f	115–120	18.79	6.3	7.89	7.17	1.32	—	—	2.04	9.0	53.6	"	0.17	62.60	85.7	40	60	—	—	—
186	A_f	0–10	20.15	6.2	7.26	6.40	5.06	0.301	9.90	none	13.7	45.8	0.17	0.29	59.50	78.5	43	65	22.0	14.6	traces
	AB_f	40–50	22.39	10.3	6.83	6.14	1.16	0.112	6.01	same	8.48	58.72	0.08	0.14	67.19	87.3	68	75	42.0	11.0	0.16
	B_{1f}	65–70	18.00	10.6	6.83	6.14	0.18	—		"	7.68	62.72	0.12	0.12	70.40	89.0	56	66	50.0	—	
	B_{2f}	90–100	18.16	9.4	6.92	6.14	0.30	—		"	6.2	60.4	0.12	0.10	66.60	90.5	39	54	56.0	—	

[a] Extraction carried out with normal ammonium acetate; Ca and sum of Ca + Mg by titration with trilon; Mg determined by difference.

[b] According to Schmuck.

dominates among the exchangeable cations. There is so much of it that in some cases the proportion of exchangable calcium to exchangeable magnesium comes close to 0.1 and almost never rises above 0.3. The large amount of adsorbed magnesium imparts salinity to the soil. This is expressed primarily in the morphology (lumpiness, compactness, viscosity and stickiness when in the wet condition, and high mechanical stability of the lumps, vertical fracturing when in the dry condition) as well as in the poor water permeability, capacity to swell, and others.

The possibility of magnesium salinity was first pointed out by academician K. K. Gedroits (2) in his studies of the compact chernozems of Kuban district. This concept of Gedroits was applied to the study of soils of the Central Urals by Ivanov and Dvinskikh (5), Nogina (8) and others. We believe that in our case we are also dealing with phenomena of magnesium salinity.

The soils of Albania under study have a very high adsorption capacity, in individual cases coming close to 70 meq. (profile 186). These soils contain an appreciable amount of mobile forms of potassium and especially of iron; they are poor in mobile phosphorus. The loss on ignition (900 degrees) of both types of soils is comparatively high, but the range of its magnitude in the individual horizons is not great.

Extremely interesting and unexpected is the relatively low humus content, in spite of the intensive dark coloration of the soils. This is especially noticeable in deep horizons, which have a black, cinnamon-brown and dark-gray color, with a humus content of 1.1 to 1.3%. Evidently, the black color of the soils is not due exclusively to humus.

In Table 2 we present data on the analysis of the organic matter (analytical work carried out in the biochemical laboratory of the Soil Institute, Academy of Sciences, USSR under the direction of Prof. M. M. Kononova). In the first place, attention is called to the sharp difference in the character of the humus in the analyzed profiles of the smolnitsy. In profile 240, we observe a very high content of mobile humic acids in the humus composition. The ratio of the humic-acid carbon to that of the fulvic acids in the lower horizons of this profile equals 4 and even 6; that is, significantly higher than in chernozems. The picture is quite different in profile 186. Here the proportion of humic-acid carbon to fulvic-acid carbon narrows down to 0.84 and even to 0.42. Simultaneously there is a sharp increase in the percentage of the carbon not extractable from the soil; that is, firmly combined with the mineral substance. It must be emphasized especially that the sharpest difference in humus composition is shown by the lower

TABLE 2

Composition of the organic matter by groups

(Analyses by N. A. Pankova)

Profile No.	Horizons & depths, cm.	Total C in % of air-dry soil	Humus (C × 1.72)	In % of total carbon					C of humic acids/C of fulvic acids	Mobile humic acids as % of total C
					C of humic acids					
				C in decalcified sample	Fraction in alkaline extract after decalcification	Total of humic acids	C of fulvic acids, total	Carbon in soil residue after extraction of humic acids		
240	A_p 0–10	$\frac{3.64}{100}$	6.28	12.9	23.9	24.7	22.0	34.6	1.13	12.6
	A_1'' 45–50	$\frac{1.98}{100}$	3.41	12.6	38.9	44.5	11.1	29.3	4.0	19.2
	A'' 95–100	$\frac{1.50}{100}$	2.59	8.0	43.3	44.0	7.3	36.7	6.0	22.0
186	A_f 0–10	$\frac{3.89}{100}$	6.71	15.2	16.7	19.3	22.8	36.7	0.84	9.5
	AB_f 40–50	$\frac{1.22}{100}$	2.10	9.0	8.2	9.0	21.3	51.6	0.42	4.9

TABLE 3

Data on the total analysis of smolnitsy soils and their clay fraction. Adsorption capacity and humus in the clay fraction. Data on the total composition of the calcined sample.

(Analyses by L. A. Bulayeva, and Z. N. Karayeva)

Profile No.	Depth, cm.	Hygroscopic water, %	Humus, % (Tyurin)	Adsorption capacity, meq.	In percent													
					SiO_2	R_2O_3	F_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Sum
240	0–10	9–80	5.00	88.21	56.99 55.69	37.12 30.90	33.00 24.19	3.73 6.04	traces	0.28 0.12	0.59 0.64	5.06 11.39	0.09 0.25	0.03 0.39	0.03 0.58	1.39 1.09	101.27 100.38
	45–50	10–98	2.60	80.68	56.65 56.05	37.59 31.21	31.85 24.19	6.69 6.99	same	0.04 0.09	0.36 0.52	5.21 10.49	0.09 0.35	0.03 0.42	0.07 0.59	0.73 1.47	101.72 101.46
	95–100	10.66	1.72	84.16	56.60 56.15	37.39 29.98	31.45 22.90	5.57 6.92	"	0.19 0.08	0.36 0.49	5.98 11.31	0.03 0.34	0.03 0.46	0.10 0.60	0.98 0.75	101.30 100.00
	115–120	4.12	1.98	78.19	58.50 46.65	36.08 18.59	31.85 17.33	4.00 0.42	"	0.23 0.16	0.31 0.51	4.88 38.19	none 0.74	0.03 0.62	0.10 0.09	0.76 1.12	100.66 100.83
186	0–10	8.04	5.76	72.45	48.01 49.50	43.50 30.60	36.65 22.88	5.98 8.13	"	0.12 0.12	0.64 1.99	7.45 11.32	0.18 0.21	0.04 0.24	0.04 0.29	1.15 1.06	100.26 100.24
	40–50	12.94	1.66	82.87	56.40 52.40	37.90 33.30	31.02 25.85	6.83 7.41	"	0.04	0.53 0.92	5.47 12.41	none 0.21	0.03 0.12	0.06 0.12	0.67 1.29	101.05 100.71
	65–75	13.86	1.07	81.32	58.95 52.79	34.90 28.45	30.95 23.00	3.87 5.45	"	0.03 traces	0.49 0.95	6.72 16.43	none 0.17	traces 0.09	0.04 0.12	0.60 1.07	101.65 100.07
	90–100	12.28	1.41	86.28	57.60 50.48	36.15 27.98	31.85 22.60	4.13 6.07	"	0.04 traces	0.43 1.08	5.92 18.20	none 0.21	0.03 0.12	0.06 0.12	0.68 1.27	101.73 100.15

horizons, while those nearer the surface differ less among themselves.

In Table 3 we present data on the total analysis of the soils (figures in the denominator) and of their clay fraction (numerator). These data are adequate evidence of the abundance of iron and magnesium in both soils, and of the almost complete absence of titanium. The unusual predominance of sulfur over calcium is noteworthy.

On separating the clay fraction from profile 240 by the process of trituration, we obtained absolute values close to those obtained by the particle-size analysis according to the Kachinski method. In profile 186, the absolute values of the clay fraction are appreciably smaller, but the course of their variation along the horizons still agrees with data from the particle-size analysis according to Kachinski. This fraction (Table 3) contains more iron than the whole soil, and shows a maximum at the upper horizons. The adsorption capacity of the clay is great and is determined by its mineral part, as indicated by the discrepancy between the highest values for humus and the adsorption capacity of the colloids. According to data from X-ray structural analysis (N. A. Sharina), the clay fraction is represented by almost pure montmorillonite. Differential thermal curves (E. A. Shurygina) proved that this is an iron-containing variety of montmorillonite, known as nontronite (Fig. 1). The data from the total analysis and the high adsorption capacity of the clay fraction fully agree with this determination (X-ray structural and thermal analyses done in the mineralogy laboratory of the Soil Institute, Academy of Sciences, USSR, under the direction of Professor N. I. Gorbunov).

Under the regular and stereo microscope: in the fractions 1 to 0.25 and 0.25 to 0.1 mm. diameter, black formations are visible. These are aggregates of various iron minerals (in particular of magnetite). We separated, especially from the heavy fraction (>2.75), a mineral having black color, conchoidal fracture, resinous gloss. It was very brittle, and when crushed disintegrated into irregular chocolate-brown flakes. In the 0.25 to 0.1 mm. diameter fraction, it formed up to 25% of the total mass. This mineral was present also in samples which had been heated to 900° C., but in somewhat smaller

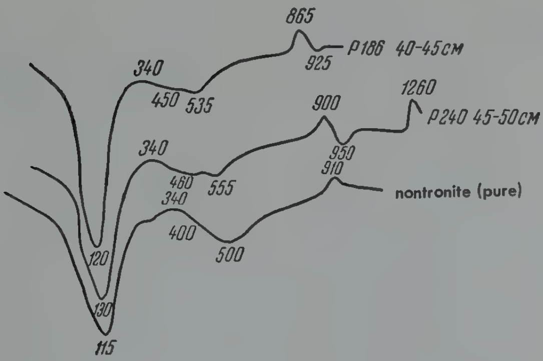

FIG. 1.—Thermograms of soils of Albania (fraction smaller than 0.001 mm. diameter) and pure nontronite.

amount, and also in samples after the wet combustion of organic matter (H_2O_2 and HNO_3).

In the publications of Ginzburg (3) we found a description of a mineral which corresponds fully in its morphology and its origin, and even in its mineral chemistry to that found in the Albanian smolnitsy. This is a hydrated silicate of iron oxide, the so-called hisingerite. Its composition is:

$$2\ (R_2^{+} + Fe_2^{+++}\ Si_3\ O_{10})\cdot 9H_2O$$

It is a colloidal variety of nontronite, amorphous or cryptocrystalline.

For this mineral, Chukhrov (13) offers the formula:

$$mRO\cdot nFe_2O_3\cdot pSiO_2\cdot \times H_2O$$

and remarks that the name hisingerite "embraces ill-studied ferrisilicate gels with this or some other amount of cations. These gels develop by the mutual or simultaneous coagulation of silica and iron oxides, or as the result of the coagulative separation from solutions of compounds of a more complex composition." According to Chukhrov, hisingerite represents a whole group of hypergenic minerals, "whose formation is linked to the weathering of iron sulfides, for instance pyrrhotite, found in silicate rocks, or to the weathering of iron silicates (it now becomes clear why the total analysis indicated an increased sulfur content)." Chukhrov names a series of minerals of the hisingerite group: avedite (Hungary), pyokhite (Bosnia), melanosiderite (Pennsylvania) and many others. All have a characteristic resinous or glassy luster, conchoidal fracture and iron-black, velvet-black, resin-black color. Their specific gravity varies from 2.5 to 3.5 and they are brittle. Noting the resemblance of hisingerite to nontronite, Chukhrov does not identify "the crystalline phase of hisingerite with nontronite." The basis for this was supplied by the investigations of Sudo and Nakamura (19), who did not detect, in a Debye crystallogram of Japanese hisingerite, the lines corresponding to 12 to 15 Å (the remaining complex of features which characterizes this mineral was noted in full).

Conclusions

1. Smolnitsy of Albania are meadow cinnamon-brown and cinnamon-brown meadow soils. They have an abundant clay fraction and a very high adsorption capacity, owing fundamentally to the mineral part of the adsorbing complex. Magnesium clearly predominates in the adsorbing complex. This imparts some salinity to these soils.

2. The unfavorable physical properties of the smolnitsy are, evidently, also linked to the presence of nontronite and especially of its colloidal variety, hisingerite. These unfavorable properties are even more intensified by the background of general magnesium salinity.

3. The black coloration and the resinous luster of Albanian smolnitsy are due to the presence of iron minerals and especially of minerals of the hisingerite group. It is possible that many black soils, such as African vlei and tirs, European smolnitsy, Indian regurs, our chernozems, and others, do contain these minerals (in Dana [4] we find indications of the presence of hisingerites

in the Maykop region, an area where chernozems are most widely distributed).

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EXPERIMENT IN SOIL PRODUCTIVITY RATINGS OF NOVOSIBIRSK REGION

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Western Siberia is distinguished by a somewhat less than favorable climate for agriculture. The winters here are severe, and the summers dry. The temperature rises quickly in the spring and in the autumn drops sharply, a situation that creates the highest anxiety in the dates of the spring plantings and the autumn harvests. Any delay is reflected unfavorably on the amount of the yield and in the completeness of the harvest in the fields of the collective and state farms.

In the past, Novosibirsk region has not actively reclaimed land and only in post-revolutionary times (especially in the last three years) have the possibilities of mechanization resulted in the reclamation of over a million hectares of virgin land. The total area cultivated has more than doubled. Nevertheless, in relation to the general area the percentage of land tilled by the region is far from the necessary maximum (Table 1).

On the whole the following soils are tilled in the Novosibirsk region, the total area of which is shown on 44 sheets of the State Soil Maps and expressed in thousand of hectares.

Chernozem, leached, medium-humic, medium thick	1008.7
Chernozem, ordinary, medium-humic, medium thick	573.5
Chernozem, solonized, medium thick	561.6
Chernozem, southern, low-humic, thin	245.6
Dark-gray forest	667.9
Gray forest	152.3
Gray forest, solodized	128.3
Chernozem, podzolized	174.9
Chernozem, leached, rich, medium thick	147.4
Chernozem, solonetz-like, medium-humic	23.0
Chernozem, solonetz-like, low–humic	23.0
Meadow-chernozem	22.8
Meadow-chernozem, solodized	242.8
Meadow-chernozem, solonetz-like	84.3
Meadow-chernozem, solonchak-like	174.2
Total	4230.3

The total area of soils indicated above corresponds almost exactly to the territory of the arable and overgrown land (4,200,000 hectares, Table 1).

The complexity of the soil cover of the region and the presence of poor land among large areas of arable soil give sufficient basis to assume that part of the chernozem and other natural arable soils are under forest or used as hayfields and grazing areas, while less fertile soils—various types of solonetzes and their complexes with humid meadow soils—are partly under cultivation.

Because some of the most fertile lands are not under maximum cultivation, the area under tillage can yet be increased; but the great areas of land considered for future reclamation must be sought in the more northerly districts with gray forest, sod-podzolic and sod-meadow soils, now covered with burned-off areas, brush, forests, meadows and pastures.

In the above mentioned 44 sheets (Novosibirsk) of the State Soil Map, the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR distinguishes the following natural districts within the region:

1. North Barabinsk: bog-forest
2. Central Barabinsk: bog-meadow
3. South Barabinsk: solonetz-solonchak-chernozem
4. Northern Kulundinsk: coarse clay-loam southern chernozems and saline soils
5. Northern Priobsk: ordinary and slightly leached chernozems
6. Novosibirsk: gray forest soils and podzolized chernozems
7. North Kuzbassk: leached and podzolized chernozems
8. Priobsk: sands with pine groves and sandy podzolic soils

According to data from these districts, Novosibirsk, North Kuzbassk, Northern Priobsk and Northern Kulundinsk have reclaimed the most land for agriculture.

A somewhat different regionalization of Novosibirsk region has been accepted by State inspection for variety trials of grain crops, in which variety tracts are distributed according to the zones shown in Table 2.

Neither of these regionalizations was coor-

TABLE 1

Land use in Novosibirsk region in millions of hectares

Total land area	Arable	Hay	Pasture and grazing	Forest and brush
18.0 100%	4.2 23%	2.1 11%	2.5 14%	3.8 21%

TABLE 2

Regionalization of the State variety trial tracts of (GSU) Novosibirsk region

Designation of variety trial plot	Zone
Northern	Lowland, subtaiga zone
Maslyanikovsk	Foothills, subtaiga zone
Vengerovsk	Northern forest-steppe lowland
Karagatsk	
Novosibirsk	
Oyashinsk	Northern forest-steppe foothills
Barabinsk	
Verkhne-Irmensk	
Dovol'nensk	
Korsuksk	Southern steppe lowland
Chistoozernyi	

TABLE 3

Characteristics of the climate in the region of variety trial tracts

Designation of GSU variety trial tracts	Zone	Mean annual precipitation 1946–1955	Sum of the positive temperatures 1946–1955	K
Maslyanikovsk	foothill damp	453	2150	4.7
Northern	subtaiga lowland	390	2132	5.5
Vengerovsk	forest-steppe normal humidity	374	2319	6.2
Karagatsk		370	2283	6.2
Oyashinsk		373	2377	6.3
Verkhne-Irmensk		350	2385	6.8
Novosibirsk		333	2312	7.0
Chistoozernyi	steppe	296	2495	8.4
Barabinsk		255	2279	8.9
Dovol'nensk		248	2312	9.3
Korsuksk	arid steppe	252	2501	9.9

dinated with data on productivity of the crops, a fact which seriously interferes with their use in agricultural planning.

In the present work an attempt has been made to relate both the data of detailed soil investigations available from variety tracts and also the basic climatic indices during the period 1946–1955 with the productivity of the grain crops of the variety tracts. Consideration of the data suggested the possibility of a somewhat different regionalization from that given in maps of the Soil Institute and by the State Selection Inspectorate. There appeared to be a reciprocal relation between the amount of mean annual precipitation and the sum of the positive temperatures. On the basis of this function we will use in the remainder of the text the coefficient obtained by dividing the totals of the temperatures by the total precipitation. The coefficient (K) rather accurately associates the natural zones of the region with the soil complexes which have been determined and with the corresponding productivity of grain crops on the variety tracts (Table 3). Thus, a coefficient lower than 5 corresponds to a specially humid foothill zone; 5 to 6 in a humid subtaiga zone; 6 to 7 in a forest-steppe zone of normal humidity; 7 to 9 in a lowland, partially arid steppe zone and higher than 9 in an arid zone.

Upon comparing the productivity of the grain crops with the coefficient given in Table 3, we get the following productivity curve (Fig. 1).

The productivity curve of the grain crop on the State variety trial tracts approaches a parabola on which the maximum yield corresponds to coefficients of 4.5 to 6.5, decreasing in proportion to an increase or decrease in the value of this coefficient.

Figure 1 indicates that the shape of the curve deviates somewhat by the action on the amount of the crop of a third factor in plant growth nutrients; this is particularly manifested for Barabinsk, Chistoozernyi and Dovol'nenskii variety trial tracts, which are situated in a zone where soils of the solonetz-solonchak complex are of wide occurrence.

Not to be located on a true parabola are the productivity data of the Oyashinsk variety trial tract, which studies the action of various agricultural methods and thus has different agricultural background than that which is acceptable for other variety trial tracts. If the curve for the zone of solonetz-solonchak soils is somewhat straightened, it is apparent that the presence of the solonetz characteristics lowers the productivity.

The relation between the grain crops from the variety trial tracts of Novosibirsk region and their soil genesis is evident from the following characterization of the soils of each variety trial tract.

1. Northern: soil investigations not carried

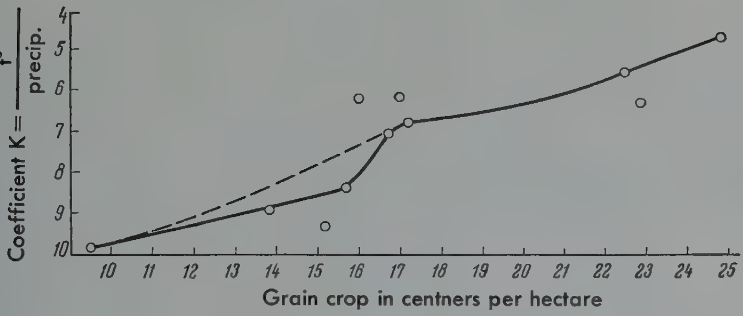

FIG. 1.—Size of the crop as a function of the value of the coefficient K $= \frac{t°}{\text{precipitation}}$

out; one can assume the presence of gray sod-podzolic or sod-meadow soils.

2. Maslyanikovsk: dark-gray medium clay loam to clay loam.
3. Karagatsk, Novosibirsk, Verkhne-Irmensk and Oyashinsk: leached chernozem, medium thick, medium humic, fine clay loam on very fine clay loam.
4. Vengerovsk: solonetz-like chernozems, fine clay loam on very fine clay loams.
5. Granular carbonate chernozems, medium humic, medium thick, clay, on carbonate clay.
6. Dovol'nensk: ordinary chernozems, medium humic, medium thick, clay on loessial fine clay.
7. Karsuksk: Southern chernozems, low-humic, thin, fine clay loam.

The data on the productivity of grain crops on the variety trial tracts is characteristic of that 80% of the area of the region with the most frequently occurring soils of tilled land. Not included in the variety trial tracts are the negligible areas of gray forest soils but chiefly soils of the meadow type.

Almost all soils indicated on the State Soil Map have some variations in texture, whereas soils of the variety trial tracts are only fine clay loams and clay. Thus, even soils having one and the same designation prove not to be included in the soil varieties of the trial tracts with a coarser texture. Not included in the variety trials type-test were the low-humic modifications of solonetz-like chernozems and all the varieties of meadow-chernozem soils, that is, chernozem soils with a high water table (three meters deep).

For the productivity rating of the complete list of soils suitable for tilling in dry farming it is necessary to introduce a supplementary correction factor in the rating number obtained by analysis of the productivity data from the variety trial tracts. Such factors are required for a change in the humus content and in the thickness of the humus layer, for texture, solonetz qualities, and a number of other criteria.

We now present the results of the analysis of the grain productivity data. Table 4 summarizes the information concerning the duration of the experiment and kind of grain crops included in the mean productivity data.

For each of the crops listed, the arithmetical mean of the productivity is calculated for the entire period of observation. The mean for all grain crops is totaled from the means for each crop and divided by the number of crops. In addition, the weighted mean of yield is determined; that is, the yield with a correction for area distribution of the particular grain crop in the region.

The results of analysis of the data obtained are summarized in Table 5.

The data in terms of the percentage of the highest yield will be designated as the site quality numbers. From Table 5 it can be seen that the arithmetical means defined more precisely the boundaries between soil and climatic zones; we will use these means to draw further conclusions.

Productivity data obtained from the analysis of the parameters of only 11 variety tracts are too few to support our further reasoning; therefore the resulting conclusions must be considered as a working hypothesis serving for analysis of more extensive zonal data on the productivity of the variety trial tracts where for each soil a

TABLE 4

Crops and duration of experiments on variety trial tracts

Designation of variety trial tracts	List of grain crops in variety trials	No. of years of experiment	Years observed	Designation of type plots	List of grain crops in type test	No. of years of experiment	Years observed
Maslyanikovsk	Spring wheat	19	1938–1956	Novosibirsk	Spring wheat	19	1938–1956
	Winter rye	18	"		Winter rye	14	1940–1955
	Oats	11	1938–1948		Oats	19	1938–1956
					Spring barley	16	1938–1956
Northern	Spring wheat	17	1939–1956		Hard spring wheat	14	1938–1946
	Winter rye	10	1938–1945 1948–1949				
	Oats	19	1938–1956	Chistoozernyi	Soft spring wheat	18	1938–1956 1940–1942
	Spring barley	9	1938–1944 1946–1947		Winter rye	6	1946, 1947
					Barley	9	1938–1947
Vengerovsk	Soft spring wheat	18	1939–1956		Hard spring wheat	14	1938–1955
	Winter rye	14	1938–1948 1950–1954				
	Barley	10	1938–1948	Barabinsk	Spring wheat	18	1938–1956
					Winter rye	16	1938–1955
Karagatsk	Soft spring wheat	17	1938–1956		Hard spring wheat	12	1938–1945 1949–1954
	Winter rye	13	1939–1955				
	Oats	17	1938–1956				
	Spring barley	5	1938–1943	Dovol'nensk	Spring wheat	19	1938–1956
	Hard spring wheat	9	1941, 1946 1948 1950–1955		Spring barley	8	1939 1949–1956
					Oats	12	1938–1949
					Winter rye	9	1939–1947
Oyashinsk	Spring wheat	17	1938–1955		Hard spring wheat	10	1938–1940 1942, 1948 1951–1955
	Winter rye	15	1938–1952				
Verkhne-Irmensk	Soft spring wheat	18	1938–1955	Karsuksk	Winter rye	13	1940–1955
	Winter rye	17	1939–1955		Spring barley	7	1949–1956
	Hard spring wheat	11	1941–1954		Hard spring wheat	15	1938–1955
					Soft spring wheat	17	1938–1956

Note. The interruption in the establishing of the experiment for one year or less of substandard crops are not included in the number of years and the mean productivity, but in the years of observation interruption of the experiment is noted for more than 3 years.

sufficient number of indices has been gathered. According to data from the Novosibirsk region variety trial tracts, the highest site quality was received by the dark-gray forest soils. North of these soils are formed poorer, less humic gray and light-gray forest soils, sod-podzolic and sod-meadow soils, on which, as is apparent from the productivity of grain crops of the Northern variety trial plots, the quality of the soils is lower; the same reduction in site quality is found to the south of dark-gray forest soils in a zone of leached, ordinary, solodized and southern chernozems, which, although they are richer in the total amount of dark-gray humus, occupy less favorable territory in relation to warmth and moisture, as is evident from Fig. 1 and Table 3. On the basis of the data in Table 5, all the soils can be arranged in the series shown in Table 6 with adequately correct spacing of the varying site qualities.

In the variety trials in Novosibirsk region there was no representation by the chestnut soils, which may occupy a rank with the lower site qualities of the order of 34–24, and so forth, while the more northerly soils not taking part in the variety trials—the gray, light-gray, sod and sod-podzolic—may be given site qualities of the order of 83–74, and so forth.

TABLE 5

Average productivity of grains according to the variety trial tracts of Novosibirsk region

Designation of variety trial tracts	Soil designation	Productivity in centners per hectare		In % of highest yield	
		Arithmetical mean	Weighted mean	Arithmetical mean	Weighted mean
Maslyanikovsk	Dark-gray forest, clay loam	24.9	23.6	100	100
Northern	No information on soils	22.5	19.1	90	81
Karagatsk	Chernozem, leached average thickness, average humic fine clay loam	16.0	14.7	64	62
Novosibirsk	same	16.8	16.7	68	71
Verkhne-Irmensk	same	17.2	12.9	70	55
Oyashinsk	same	22.9	21.9	92	93
Vengerovsk	Solonetz-like chernozem, fine clay loam	17.0	15.3	68	65
Chistoozernyi	Carbonate chernozem, medium-humic on carbonate clay	15.7	15.8	63	67
Barabinsk	Chernozem, solodized average fine clay loam	13.8	12.8	55	54
Dovol'nensk	Ordinary chernozem, medium humic, medium thick clay	15.2	14.9	61	63
Karsuksk	Southern chernozem, low humic, thin fine clay loam	9.5	9.3	38	39

TABLE 6

Site quality index

Soil	Site quality index
Sod-meadow and gray forest	84–93
Dark-gray forest	94–100
Leached chernozem	73–64
Ordinary chernozem	63–54
Solodized chernozem	53–44
Southern chernozem	43–34

In future work this series of site qualities figures will be modified since the productivity of the variety testing tracts with the same sorts in other regions will be used for the zone as a whole.

The site quality rank shown in Table 6 for leached chernozems (73 to 64) is obtained from Table 5, in which this rank, according to actual productivity, was represented as 22.9 to 16.0 centners per hectare (relative values of 92 to 64%). The high site quality (92) applies to the crop at variety trial tract Oyashinsk GSU, which, as mentioned above, is studying the action of different agricultural practices with respect both to the agricultural background and also to the productivity. This cannot be placed in the same series with variety trial tracts having the same soils but which conduct their experiments against uniform, comparable backgrounds. For this reason the productivity data of the Oyashinsk variety trial tract have been excluded in making up the site quality series for leached chernozems. The productivity of the remaining three variety trial tracts with leached chernozems is placed in the site quality rank shown as 73 to 64.

All the remaining relative production values shown in Table 5 have been assigned to site quality ranks in Table 6. All of the solonetz-like chernozems of the Vengerovskii variety trial tracts have been assigned to the same rank with the leached chernozems, while the granular carbonate chernozems of variety trial tract have been placed in the same rank with the ordinary chernozems.

From the designations of the soils listed in Table 5 it is seen that they all have the same texture (fine clay-loam and clay), but many of the arable soils are divided, in turn, into varieties on the basis of their texture. For this reason we must make the broader site quality ranks more precise for soils of different textures. When the texture of a soil changes, so do its physicochemical properties, its air-water relations, and, also, its productivity. Since the influence of the texture on the crop yield prevented the establishment of realistic figures for the productivity of the variety trial tracts of Novosibirsk region because of their small number, the recommendation is made that the site quality series be divided into groups within soils of a single genetic designation, taking into consideration:

1. The extent to which the soil has been fertilized, which is definitely reflected in the figures of the site quality series. There is every reason to believe that the least productive crops are associated with soils which have in the past been only slightly fertilized, while the highest crops are obtained from the most fertilized land.

2. The texture of the soils, which exerts a considerable effect on the variation in yield. The largest crops correspond to the best air-water relations in the soil as found in medium silty clay loam; a texture which is finer (more clay) or coarser (sandy loam) leads to a decrease in productivity, that is a decrease in the site quality figure.

3. Chemical properties of the soil, its acidity, solonetz-like characteristics, extent to which leached and solodized, all affect the nutrient conditions, thus increasing or decreasing the crop. The effect of the solonetz-like characteristics has already been considered in the explanation of the curve in Fig. 1, and this can also be done for total soil humus, thickness of the humus layer, prominence of the podzolic horizon, and so forth.

4. The local relief, inasmuch as all depressions in it increase the soil moisture and create conditions either for an increase in the crop (in the arid zone) or for a decrease in it (in a zone of excessive moisture).

Analyzing the importance of all the factors listed for soils of a single designation, several groups may be set up according to the site quality. For Novosibirsk region, using site quality series with small intervals, it is possible to divide the soils into three groups. For Western Siberia as a whole, using large intervals, five, six or more site quality groups may be distinguished. The following characterization of the end groups may be given:

First Group. The better soils of the site quality series have a medium clay loam texture, much previous fertilization, and include reclaimed virgin chernozems. The soils are leached slightly or not at all and have negligible acidity. They are slightly podzolized. A high humus content and a thick humus horizon are characteristic. These soils are located on the more level elements of the relief and, in arid regions, in flat depressions. Bog, solonetz and solonchak formation takes place in these soils either to a very slight degree or not at all.

TABLE 7

Site quality of the soils of Novosibirsk region

Soil designation	General site quality	Site quality index for soils of different groups		
		I	II	III
Sod-meadow and gray forest	84–93	93–90	89–87	86–84
Dark-gray forest	100–94	100–98	97–96	95–94
Leached chernozem	73–64	73–70	69–67	66–64
Ordinary chenozem	63–54	63–60	59–57	56–54
Solodized chernozem	53–44	53–50	49–47	46–44
Southern chernozem	43–34	43–40	39–37	36–34

Third Group. The inferior soils of the site quality series have a coarse texture (sandy loam); they have been cultivated very little or are virgin land. The type is that of a thin podzolic soil with a podzolic horizon reversed on the surface. The soils are strongly leached, acidic and podzolized, the humus content is small, the humus layer thin. These soils are found on slopes showing signs of soil erosion. There are signs of swamping in the root layer or the presence of solonetz, solonchak or other unfavorable properties of the soil which strongly decrease the crop yield.

Inasmuch as nine stages were planned for the site quality series of the soils of Novosibirsk region, one may consider conditionally that the first three with the highest grade can be used for the best soils, the three last for the poorest soils. When the site quality of the soils of Novosibirsk region is calculated, the site quality series as a whole may appear as shown in Table 7.

As more data accumulate on each soil and its site quality groups, these figures will become more precise. The example of site quality evaluation cited shows very obviously that different soils make possible the growth of crops of different sizes. These tables can make a more precise evaluation of the productivity of 100 hectares of useful land and be of considerable help in introducing special agricultural methods for growing large grain crops.

Conclusions

1. By site quality rating is meant the relative yield of grain crops. The highest rating of 100 points designates a soil which has produced the

largest crop, averaged over many years. The site qualities of all other soils are calculated by the ratio of their actual productivity to that of the soil given 100 points.

2. The correctness of the site quality of soils according to the productivity of the crops averaged over many years depends to a considerable degree on compliance with uniform methods of calculating and growing the crops used to derive the mean productivity data, and for this reason data from the State Selection Inspectorate was used for site quality.

3. As shown by the data given in the article, the degree of fertility is not always directly related to the total amount of humus in the soil; the usual criterion of its quality. In site quality consideration must be given to a complex of factors affecting soil fertility.

4. A favorable ratio of temperature to precipitation in the zone in which dark-gray forest soils are widespread made possible greater exploitation of their fertility and the assignment of a higher site quality rating even in comparison with soils having a higher humus content.

5. If the soils have previously been fertilized to the same extent (either great or small), the effect of the soil genesis is not masked, and the order of the relative value of the soils is preserved. Thus, in the present paper, the recommendation is made that consideration be given to dividing the indices of site quality for each soil in groups according to their qualifications in the horizontal series (see Table 7), in addition to grouping the soils by genesis in a vertical series of site qualities.

6. Site qualities related to soil contours on maps make it possible to judge the potential productivity of separate areas or tracts of land. This makes it possible to determine the profitability of growing crops and the cost (productivity) of labor per unit of area or crop.

7. The availability in the USSR of a large number of soil maps compiled on the basis of a relatively uniform (genetic) soil classification will, with proper use, make it possible to hasten the indexing of site quality of soils.

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THE POSSIBLE ROLE OF MICROORGANISMS IN INCREASING THE EFFECTIVENESS OF GROUND ROCK PHOSPHATE AS A FERTILIZER (A Review)

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The total phosphorus content of soils ranges approximately from 0.025 to 0.3% of P_2O_5. In a hectare this amounts to about 625 to 7500 kg. of P_2O_5, only a part of which is available to plants. Soil phosphorus is represented chiefly in the form of various basic phosphates of calcium, iron, aluminum, and so forth. A significant part of the soil phosphorus (up to 50%) can be combined with organic matter in the form of nucleoproteins, lecithin, phytins, sugar and alcohol phosphates, humic-phosphates, and so forth. Most of these organic compounds of phosphorus are slightly available or are completely unavailable to plants and are assimilated only after they have been decomposed or mineralized. In studying the soil productivity we must ascertain the amount in them both of the phosphates which are more soluble and easily available to plants and also of the common phosphorus compounds which are slightly soluble and barely available.

In large-scale practice we must consider the possibility of an inadequate amount of phosphorus which is available to plants. This inadequacy is related to a lack of phosphates in parent material as well as to a soil depletion by preceding crops. A certain amount of phosphorus does return to the soil with manure, which contains 0.2 to 0.3% P_2O_5. Phosphorus found in grain, milk, meat, wool, and so forth but not in manure, may be supplied by supplementary application of synthetic mineral phosphorus fertilizers.

A primary feature of superphosphate—a universal phosphorus fertilizer—is the rapid transfer into the soil of phosphorus in its less soluble form. Therefore, replacing manufactured superphosphate by a cheaper form of phosphorus fertilizer—ground rock phosphate—is entirely justified.

The task of agrochemical science is to define more clearly the conditions under which rock phosphate can successfully replace superphosphate and to evaluate its effectiveness. A number of agrochemical investigations have studied basic factors concerning the effectiveness of ground rock phosphate as a phosphorus fertilizer. They include: acidity of the soil, its content of organic matter, physical and hydrothermal soil conditions, specific characteristics and peculiarities of plants, other fertilizers in the crop rotation, and other agricultural practices. Results of investigations in this field for the last 40 to 50 years were comprehensively reviewed by us in a separate paper (2). To develop a positive effect on crops of the phosphorus derived from the slightly soluble calcium phosphates (tricalcium phosphate, rock phosphate, bone meal, and apatite), increased solubility is clearly necessary. This occurs primarily in soils having an acid reaction or which have had phosphates applied under plants with acid root secretions (lupine, mustard, etc). The specific peculiarities of individual plants in respect to the slightly soluble calcium phosphates also have an importance which is sometimes critical. However, primary emphasis is placed both on the acidity of the soil (or nutrient medium) to increase the effectiveness of the rock phosphate and also on the need for considering the soil properties when applying phosphate as a fertilizer. For example, phosphate must not be applied to carbonate soils or even to acid soils after liming, for then soil acidity is considerably neutralized.

Several other explanations in the agrochemical literature concerning the positive effect of rock phosphate ultimately depend on soil acidity. For example, the works of Butkevich (4) refer to the importance of a buffer solution in the rhizosphere for the assimilation of phosphorus from rock phosphate. It follows from them that a decrease in the buffer capacity of the $Ca(HCO_3)_2$ solution can easily be overcome by the plant specifically when there is an acid reaction of the soil medium.

In this paper we have reviewed existing data in the literature concerning the possible role of microorganisms in increasing the effectiveness of rock phosphate as a fertilizer. The function of living organisms in the decomposing of slightly soluble compounds, phosphates in particular, is of definite interest. Severin (16) wrote on this question: "It is impossible that the mineral and organic acids and alkalies being formed continuously under the influence of a whole series of microbiological processes should not also draw the soil's mineral components into the general cycle, changing in particular the slightly soluble soil phosphates into easily soluble form, and vice versa. However, the easily soluble phosphoric acid would not be reconverted into a slightly soluble form of organic phosphorus compound of the bacterial cell by way of metabolism by these same bacterial cells." He also wrote: "It is impossible that a microbiological process establishing soil fertility would not be involved in the creation of one of the components of this fertility, namely, in the formation of a soluble phosphate easily assimilated by the plants."

Vernadskiy (6) considered that the most active chemical substances in the earth's crust are radioactive elements and living matter. About the role of living matter, he wrote: "Undoubtedly all the chemical reactions in the crust of the earth are tremendously disturbed by these manifestations of life. Owing to this, the history of the chemical elements is entirely different than it would be if the chemistry of the earth's surface were governed only by the composition and thermodynamic field of this surface. We know that because of these phenomena an enormous part of the chemical elements of the biosphere are taken up by living matter and are directed to chemical reaction channels other than those in which they would proceed if there were no life on the earth."

At the beginning of the 20th century a number of investigators analyzed the influence of bacteria on the solubility and availability to plants of slightly soluble highly basic calcium phosphates, bone meal, tricalcium phosphate, and so forth (27, 28; 22, and so forth).

In the last ten years interest has again been revived in the biological study and explanation of the utilization by plants under various conditions of the almost insoluble and unavailable phosphates of calcium, rock phosphate, and apatite. We are referring here to studies on the role of microorganisms. We decided to consider these new data in the light of results obtained previously on this subject by different authors and to direct the attention of microbiologists to the need for carrying out more profound research to provide a scientific foundation for practical recommendations to the agricultural industry.

It is known that the parent material, as well as the mineral part of soils, can be decomposed by the action of microorganisms in the presence of a source of available energy. Various inorganic and organic acids formed by microorganisms develop a solvent action on these rocks (Müntz, 23, cited by Waksman, 30). Stoklasa (27) made experiments growing oats to study the influence of bacteria on bone meal decomposition. Soil for the experiment was previously sterilized, then innoculated with bacteria, including *B. megaterium, B. mycoides, B. proteus, B. butyricus,* and *B. fluorescens liquefaciens.* In different treatments, glucose or xylose was added to the dishes. Increases in the grain harvest averaged up to 50% and up to 33% of straw. Unfortunately, the experimental plan did not provide glucose and xylose controls, so that a definite conclusion as to the independent, positive action of microorganisms alone on the decomposition of bone meal could not be made.

Stalström (26) made composts of chemically pure $Ca_3(PO_4)_2$ and previously sterilized peat and straw. By inoculating these composts with various bacteria he established a marked difference in the solubility of phosphorus under experimental conditions depending on the nature of the decomposing organic matter. Bassalik (19) studied the influence of nitrifying bacteria on the decomposition of different silicates and apatite. Under the influence of respiration products these bacteria proved capable of dissolving considerable amounts of pulverized silicates. The formation of organic acids by *B. amylobacter* made this process possible. Apatite dissolved to some extent in carbonic acid and to a considerably greater extent in the presence of bacteria which released organic acids. According to the author's data the presence of bacteria also increased the ability of the roots of higher plants to cause decomposition.

Thompson, Smith, and Brown (29) investigated the assimilation of water-soluble phosphorus of the soil and phosphorus from $Ca_3(PO_4)_2$ by different mold fungi and by azotobacters (*Azotobacter chroococcum*). One-half gram of dextrose was added in the experiment; incubation was maintained for 21 to 90 days. In comparison with sterile cultures azotobacter inoculation showed a reduction in the amount of water-soluble phosphorus in the soil of 2.4 to 3 mg. of P_2O_5; in the presence of $Ca_3(PO_4)_2$ the decrease in the amount of water-soluble phosphorus was still more significant. On the other hand, in subsequent treatments of the experiment, inoculations increased the amount of phosphorus. The authors assumed that under the experimental conditions two processes went on concurrently: assimilation of water-soluble phosphorus by azotobacter and accumulation of phosphorus in the solution as a result of the death (autolytic fermentation) of some generations of azotobacter. Experiments have demonstrated that species of fungi—penicilliums—and azotobacter assimilate various amounts of phosphorus from $Ca_3(PO_4)_2$.

Chapter 23 of Waksman's monograph (30) reports interesting data on the transformation or conversion of various mineral compounds by microorganisms. The following processes are noted by him: 1) utilization by bacteria of some mineral elements (S, Fe, Mn, and others) or their compounds as sources of energy; 2) utilization of different oxygen-rich salts (nitrates, sulfates) as sources of oxygen under anaerobic conditions; 3) partial conversion into mineral compounds and partial reassimilation of dead plants, animals, and organisms which have been decomposed by soil microorganisms; 4) conversion in the presence of energy sources of simple inorganic salts, especially phosphates, potassium salts, and sulfates, into organic complexes (a part of these substances is often liberated again in mineral form with the death of the organisms and the decomposition of bacterial cells); 5) indirect conversion of mineral compounds in the soil by products of bacterial metabolism. Phosphates, sulfates, and salts of K, Ca, and Mg, which are the most important compounds in the metabolism of microorganisms, are recovered in considerable amounts from the soil solution and are synthesized in the plasma of organisms (with the decomposition of vegetable and animal residues, salts of phosphorus and potassium are again released); 6) participation by fungi in the decomposition of soil's mineral components is more active than that of root secretions of higher plants.

A special section in Waksman's monograph is devoted to the ability of soil microorganisms to convert $Ca_3(PO_4)_2$ into more soluble forms. Experiments showed that of 25 species of bacteria isolated from the soil, 12 exhibited a definite solvent action on rock phosphate, bone meal, pure $Ca_3(PO_4)_2$, $CaHPO_4$, and $CaCO_3$, if the nutrient medium was provided with a source of energy (several types of sugars), while calcium salts decreased the solubility of phosphorus. Waksman considers the dissolving of phosphorus a secondary process dependent on the action on insoluble phosphorus compounds of the carbon and nitrogen liberated by the metabolism of microorganisms. Thus, according to Waksman, the increase in the solubility of the phosphorus of $Ca_3(PO_4)_2$ and other highly basic phosphates of calcium is connected with the vital activities of microorganisms. In the presence of an excess of energy-source material, however, the synthetic activity of microorganisms can also lower the amount of easily soluble soil phosphorus. From Waksman's data it follows that the amount of available phosphorus results from the total activity of the microbiological population of the soil, including the formation of acids, secondary reactions, and synthesizing activity.

In Severin's experiments (16) the amount of soluble phosphorus in dead, sterile soil was shown to be greater than in soil in which bacterial life proceeded vigorously (judging by the liberation of CO_2). In one of the experiments there was 0.0192% P_2O_5 in the original soil, 0.0197% in the sterile soil, and 0.0102% in the inoculated soil. That is, in comparison with the control, at the time of the experiment the amount of soluble phosphorus increased 2.6% in the sterile soil, and in the inoculated, on the other hand, it diminished by 46%. The author concluded that, under the conditions of his experiment, along with the primary process of solubilizing and dissolving phosphorus there also took place a reverse process of the consumption of easily soluble phosphorus—both of that existing in the soil before the experiment and also of that which was formed during the experiment.

Part of the easily soluble phosphorus could also undergo revision in the soil.

Later experiments of Severin (16a) showed that molds requiring P_2O_5 obtained phosphorus from the barely soluble phosphates for the formation of their cells. According to him, the dissolving of phosphates by molds was due to their formation of organic acids (oxalic, citric, etc.), which had a stronger action than did root secretions. Severin (16a) cited the work of Perotti (24), who attempted to explain the physiological acidity of ammonium sulfate by the effect of fungi rather than plants. The harvest was decreased when the acidity of the medium in which the bacteria were killed was increased, and the fungous mass increased.

Salström (26) showed that the passage into solution of tricalcium phosphate is helped by butyric and lactic fermentation, and, in the case of manure, by acetic fermentation. Koch and Kröber (22) demonstrated that under the influence of biological processes everywhere, part of the insoluble phosphorus was changed into soluble form, and only in the presence of $CaCO_3$ did phosphorus fail to go into solution.

In the studies surveyed above, the solubility of phosphorus under the action of bacterial activities was confirmed. However, in some instances acidification of the medium was not observed and it was asserted that the pH of the medium was not always a decisive factor determining the degree of solubility of slightly soluble phosphates of calcium. Also, there was another active force: the microbiological factor (microbiological life in the soil). Interesting from this point of view was the published investigation of Johnston (21) on the solubility of di- and tricalcium phosphate in various organic acids (for details see below).

Numerous investigations described in Waksman's monograph suggest some conclusions on the role of microorganisms in increasing the solubility and availability to plants of $Ca_3(PO_4)_2$, rock phosphate, apatite, bone meal, and other highly basic phosphates of calcium. The majority of these investigations attaches primary significance to the ability of a number of microorganisms (bacteria, fungi, and algae) to acidify the medium. But it is accepted that in the metabolic process the effect of microorganisms in the conversion of barely soluble phosphates might be connected not only with their secretion of acids but also with the enzymatic activity and the decomposition and synthesis of phosphrous-containing compounds. In the latter case the effect of the microorganisms could also be negative. To evaluate the effect of acidification of the medium by microorganisms on the solubility of highly basic phosphates of calcium ($Ca_3(PO_4)_2$, bone meal, rock phosphate, and apatite), investigations were made in recent years in various nutrient media and in sterile soil, and with soil extract inoculations, that is, by a complex of different microorganisms or their individual species. Some have studied the significance of individual organic acids or their salts with alkaline metals as possible products of metabolism of microorganisms. We will review some of these works.

Pikovskaya (14), showed the ability of the widely distributed soil ammonifier *B. mycoides* to dissolve $Ca_3(PO_4)_2$, and considered, in spite of many recognized ideas and facts (9), that nitrification does not increase the solubility of $Ca_3(PO_4)_2$. It is interesting that according to other data (30) with the conversion of nitrogen in the soil the dissolving of highly basic phosphates occurs in the stage of formation of nitrous acid. The conversion of the latter into nitric acid is not accompanied by an increased acidity of the medium.

Muromtsev (10) isolated five microorganisms (four bacteria and one actinomycete) from the soil under winter wheat. These actively dissolved $Ca_3(PO_4)_2$. A. S. Sitnikova reported that in 1955 she had isolated in almost insoluble Kara-Tau rock phosphorate a microorganism which dissolves it (cited by Ilyaletdinov [7]). Like Severin (16, 16a), these investigators also assumed that there was a connection between the bacterial activities and the dissolving of rock phosphate [see also the works of Krassilnikov and Kotelev (8) and of Fedorov (18)].

In Ilyaletdinov's experiments (7) on nutrient medium with rock phosphate, saccharose, and $(NH_4)_2SO_4$ an increase was observed in the amount of phosphorus in the culture fluid. At the end of the experiment the amount of mobile phosphorus was considerably less. Ilyaletdinov accepts the view of the earlier investigators that, at some stage in the development of bacteria, the mobilization of phosphorus from rock phosphate terminated, but consumption of phosphorus by the bacteria did not. He attributes the mechanism by which phosphorus from rock phosphate went into solution under these experimental conditions only to the formation of organic acids with the oxidation of sugar and does not take into account the possible influence of the physiologically acid ammonium sulfate.

On the basis of the experiments conducted, Muromtsev (11, 12) concludes that regardless of the equilibrium pH of the medium, the more intensively the culture of the phosphate-dissolving microorganisms developed, the greater the amount of mobilized phosphorus. He assumes that the more vigorously the bacterial culture developed, the greater the concentration of its metabolic products—particularly of those products which interact to dissolve the rock phosphate (for example, organic anions—oxalates, citrates, tartrates, and so forth—which give almost insoluble compounds with Ca, interact with the almost insoluble calcium phosphates. The solubility of the latter is then increased).

To verify his hypotheses the author referred to the investigations of Serdobol'skiy (17), who demonstrated the intensive dissolving of calcium phosphates when they reacted with salts of various carboxylic acids (citric, oxalic, and others). Concerning Serdobol'skiy's experiments we mention that the interaction of tricalcium phosphate and the following solutions of sodium salts (but not of the acids) was studied: 0.5 M solution of sodium citrate or 0.4 M solution of sodium tartrate. No differentiation was made in these experiments between the effect of the anion and the cation of the salts on the increased transfer of phosphorus into solution in the presence of a weakly alkaline reaction. We do not believe, with the other investigator, that similar conditions can be created in the soil by carboxylic and amino acids and other organic compounds as products of the vital activities of different microorganisms. For this we would have to agree that into the nutrient medium the microorganisms excrete *salts* of alkaline metals and organic acids in concentrations approaching those of Serdobol'skiy's experiment (0.4 to 0.5 M).

The works of Gerretsen (20) and Johnston (21) are of considerable interest from this point of view. To establish the role of microorganisms in the assimilation of phosphorus by plants during the growing period, Gerretsen conducted experiments with plants under sterile and non-sterile conditions with subsequent estimation of the crop and its phosphorus content. The experiments, carried out according to Neubauer's method, gave positive results.

Using the pot-technique of Mitscherlich with oats, Gerretsen inoculated sterilized pots with garden soil and obtained positive results with constant amounts of ferrous iron, Algerian rock phosphate, bone meal, $CaHPO_4$, and $Ca_3(PO_4)_2$. Judging by the increase in the harvest and its P_2O_5 content, there was a clear-cut increment. Gerretsen concluded that microorganisms are capable of transforming slightly soluble calcium phosphates into a form accessible to plants. We must emphasize that although the presence of microorganisms had a considerable effect in these experiments, there were also approximately the same absolute increases, both in $CaHPO_4$, and in insoluble $Ca_3(PO_4)_2$ and bone meal but the increase in the harvest was less with rock phosphate.

In another series of experiments Gerretsen studied the effect of pure cultures of bacteria on the availibility to plants of phosphorus from rock phosphate. His experiments with pure cultures confirmed the results obtained by inoculating a mixture of bacteria (by adding garden soil to the sterile cultures).

Gerretsen demonstrated the essential role of soil microorganisms of the rhizosphere in conversion of the barely soluble calcium phosphates to a form accessible to plants (depending on the genus of the plant, the nature and quantity of root secretions, the number of phosphate-dissolving microorganisms present, the form of the applied phosphates, and the pH and temperature of the soil). On the basis of the experiments Gerretsen concluded that microorganisms play an important role in the assimilation by different plants of phosphorus from insoluble and slightly soluble phosphates. He showed that in most cases a change in pH of the medium did not play a decisive role in increasing the availability of phosphorus in the treatments of the experiments involving inoculation (see below). Here it is important to note Gerretsen's general conclusion that microorganisms which dissolve phosphorus are present in all normal soils. Therefore, it is not necessary to add them to the soil in order to improve the phosphorus nutrition of plants.

In the paper cited before Johnston studied the effect of more than 20 organic compounds (di- and tricarboxylic acids, hydroxy acids, amino acids and aminocarboxylic acids, sulfonates, aromatic compounds, and so forth) on the solubility of di- and tricalcium phosphates. It was established (qualitatively and quantitatively) that quite a number of these acids were capable of dissolving both of these forms of calcium phosphate. Results of the experiments showed that the solubility of the phosphates depends not only in the pH of the medium but also on specific structural characteristics of these acids.

By means of comparisons with Gerretsen's work in which groups of phosphate-dissolving bacteria were isolated, Johnston showed a similar but still stronger dissolving action of various species of fungi (*Aspergillus niger, Citromyces*). He assumed that these fungi were capable of releasing considerable amounts of citric acid and some other acids when grown in a medium containing sugar.

The most curious result of Johnston's work was that, in spite of the low dissociation constant of these weak organic acids compared, for example, with strong mineral acids (HCl and others), specific features of their structures caused the dissolving of a considerable amount of the phosphorous from the slightly soluble calcium phosphates. From the comparative data we conclude that under the conditions of the experiment the concentration of the H-ions (pH) of the medium was not the main factor in solubilizing phosphorus from highly basic phosphates of calcium. The author concluded that the molecular structure of these organic acids was the most important factor in this respect, while the greatest solubility of the calcium phosphates was brought about by aliphatic hydroxy acids or aromatic acids derived from CH_3COOH (with one exception: in "pyromucic acid"). It was not clear what the potential acidity (buffering capacity) of these organic acids was. If greater differences had been observed here, then their dissolving capacity with respect to $Ca_3(PO_4)_2$ could be compared with the value of the hydrolytic acidity of the soil for decomposition of lime, $Ca_3(PO_4)_2$, rock phosphate, or apatite, even when the pH value of the medium was not sharply defined (1).

Investigations of the All-Union Institute of Agricultural Microbiology have been devoted to the role of certain bacteria in increasing the availability to plants of tricalcium phosphate and rock phosphate (3, 13, 15).

On the basis of the data obtained some authors (Uarova and Nesterova, [3]) assumed that they had been successful in isolating, from the root system of wheat and millet and from composts, pure cultures of bacteria which increased the solubility and availability to plants of tricalcium phosphate. The isolated cultures of these bacteria were then used by the authors for increasing the solubility of the phosphorus of the rock phosphate applied to the compost. The data gathered in field experiments with bacterially treated peat-manure composts containing rock phosphate show, in our opinion, that reliability of positive results lies within the limits of accuracy of the field experiment. The results obtained (9 to 15% increase in the harvest) depended to a marked extent on the genus of the plant (potatoes, barley), the type of peat (transitional or lowland), and on the form of phosphorus (tricalcium phosphate, rock phosphate, or apatite) and could not be attributed chiefly to bacterial treatment of the composts (there were no clear statements in these papers on the specific gravity of the bacterial matter in relation to the effectiveness of composting).

The primary conclusion of these papers on the positive effect of the application to peat-podzolic soils of bacteria which split tricalcium phosphate and certain experiments carried out to find the explanation for the increase of effectiveness of ground rock phosphate must, in our opinion, be considered as insufficiently founded (13), and a recommendation for the introduction of this method into large-scale agriculture is premature (see also results of Gerretsen's studies mentioned before [20]).

Thus, we must recognize that in spite of continuing study of the possible role of microorganisms in increasing the availability to plants of the more basic calcium phosphates, the projects carried out in the last ten years have not led to productively significant results. However, some authors keep insisting on the value of the artificial application to the soil of certain kinds of phosphate-dissolving bacteria. Further microbiological experiments, directed toward a study of the role of different microorganisms (bacteria and fungi) in comparison with other factors in increasing solubility and availability to plants of phosphates, should clarify this question. Moreover, a sufficiently critical approach without preconceived conclusions is necessary. Only this kind of approach, with an adequate experimental basis, will be useful in developing this theory and the correct recommendations to agricultural production.

Conclusions

1. A summary of agrochemical investigations for the last half century has shown that the basic factors in the effectiveness of rock phosphate and other slightly soluble calcium phos-

phates are the acidity of soils, the specific characteristics of plants (acidity of their root secretions), certain agricultural practices, and so forth.

2. The data from the literature concerning the significance of microorganisms in increasing the availability to plants of barely soluble and little available basic calcium phosphates show the following:

a) In a series of experiments microorganisms (different species of bacteria and particularly of fungi) acidified the reaction of the medium (nutrient solution or soil), which should have increased the solubility and availability to plants of the more basic calcium phosphates.

b) Microorganisms (bacteria and especially fungi) were able to assimilate the nonbasic calcium phosphates and at the same time partially to dissolve phosphorus during the metabolic process connected with the secretion of different organic acids into the medium.

c) The relative importance of the work of microorganisms in general and of their individual species among the other factors increasing the availability to plants of insoluble calcium phosphates (acidity of the medium, solubilizing action of the root systems of plants) has not been developed sufficiently in the literature. It requires further study, as does the question (of importance in production) of the need to add specific microorganisms under certain soil conditions (to peat-podzolic soils) to increase the utilization by plants of the more basic calcium phosphates.

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THE INFLUENCE OF VARIOUS METHODS OF DEEPENING THE SURFACE SOIL ON THE AGROCHEMICAL PROPERTIES OF PEAT-PODZOLIC SOILS

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This article gives results of observations on the nutrient status in the peat-medium podzolic clay-loam soils of the Stepanovkoye State Farm (Moscow region) using various methods of deepening the surface soil. The methods are: ordinary plowing to a depth of 20 cm.; plowing in some of the podzolic horizon down to 25 cm.; soil-improvment plowing to a depth of 40 cm. (where the peat horizon is mixed with horizon A_2–B_1 at 3:1); and deep plowing to 60 cm. (5).

Table 1 shows the agrochemical soil indices of the experimental tract by genetic horizons at the beginning of the experiment.

With various methods of plowing, the modifications of the experiment differed in texture, physical properties and agrochemical indices as a result of redistribution of soil horizons along the profile. Thus, the clay content in the upper 20 cm. horizon increased from 12.5% with ordinary plowing to 18.0% with soil-improvement and to 20% with deep plowing.

According to Pavlovskiy and Makarov (6), with soil-improvement and deep plowing in the 20 to 40 cm. layer there was a decrease in the soil compaction, an increase in the general porosity and aeration, and an increase of permeability. Total moisture content in the 0 to 60 cm. horizon increased with deeper plowing, as compared to ordinary plowing.

Table 2 gives part of the data from observations of the total adsorbed cations and soil acidity by modifications of plowing over a three-year period. The data show that as a result of redistributing the horizons at the beginning of the experiment, the sum of adsorbed cations in the 0 to 10 cm. horizon with deep plowing, increased to 10.2 meq. in comparison with 6.5 meq. in control plowing. At the same time, the hydrolytic acidity increased from 4 to 5.1 meq. The pH value decreased. Thus, for the plow layer with ordinary plowing the pH value was 4.8, while it was 4.2 in the 0 to 20 cm. horizon with deep plowing. The amount of mobile aluminum increased from 1 to 7.2 mg. per 100 gm. soil with deep plowing. These figures changed little with soil-improvement plowing in comparison with ordinary plowing. However, at a depth of 20 to 30 cm. the soil pH increased and the mobile aluminum content decreased. With plowing in the podzolic horizon all the agrochemical indices listed remain unchanged and their values were the same as with ordinary plowing.

During the 1952 growing season when oats were planted and 60 kg. of ammonium nitrate nitrogen and 45 kg. each of soluble potassium chloride and superphosphate were applied, there was an increase in the total adsorbed cations both in the upper (0 to 20 cm.) horizon and also in the lower (20 to 40 cm.) horizon. This may have been related to the decomposition of a layer of perennial grasses which came up in the autumn of 1951 at the beginning of the experiment. The hydrolytic acidity in the different modifications of plowing during the growing season did not change. Exchange acidity of the surface soil in all modifications decreased. This took place at the expense of the hydrogen ions more than the aluminum ions.

Subsequent observations of the agrochemical soil properties over a two-year period with various methods of deepening the surface soil showed that in modifications without the application of lime, the value of the hydrolytic acidity, the amount of mobile aluminum and the pH of the salt extract remained unchanged. Thus, the harmful action of the acidity, which was caused by inversion of the illuvial horizon to the surface soil, can be eliminated only by liming.

The total adsorbed cations are more dynamic in the years of crop rotation. On plowing the grass layer in which a large amount of organic residue was decomposing, the total adsorbed cations increased, especially in the horizons of fermenting odors. In the following year, when the plow-layer was inverted, the observation was made in a fallow field. There, the total adsorbed cations decreased. This was noticeable even in the third year under a crop of winter wheat receiving 60 kg. of ammonium nitrate and 45 kg. of soluble potassium chloride and superphosphate.

Liming of the peat-podzolic soil (to half of the hydrolytic acidity of horizon A_1) did not noticeably change the content of the total adsorbed cations with soil-improvement and deep plowing. It was only slightly increased with ordinary plowing. After liming there was a significant decrease of soil acidity: with ordinary plowing in the 0 to 20 cm. horizon the exchange acidity was completely eliminated. The hydrolytic acidity underwent a twofold decrease while the pH value of the salt extract increased 0.5 to 1 units; with soil-improvement and deep plowing the hydrolytic acidity decreased 1.5 times, and there was a considerable decrease in the amount of mobile aluminum. Thus, with deep plowing in the 0 to 20 cm. horizon the amount of aluminum was reduced from 4.9 to 7.2 mg. to 0.1 to 2.2 mg. per 100 gm. of soil.

The oxidation-reduction potential was measured at 15, 30 and 50 cm. in studying oxidation-reduction conditions. Permanent glass electrodes with platinum elements were used for the measurement. In the 1954–55 drought periods the oxidation-reduction potential of the soil from the middle of June to the second half of September did not fall below 600 mv., but at certain dates values as high as 730 to 790 mv. were obtained. In spring when the moisture was close to the field capacity, the oxidation-reduction potential decreased at a depth of 15 cm., 350 to 400 mv., at 50 cm. depth with ordinary and with soil-improvement plowing, 640 to 650 mv. With deep plowing in the same 50 cm. horizon, but with excessive soil moisture a decrease in oxidation-reduction potential down to 340 mv. was noted. With the advent of the dry period its value in the 50 cm. horizon quickly rose.

Table 3 shows a distinct decrease in the oxidation-reduction potential at a depth of 15 cm. on fallow land during the growing season when the plow layer was deepened to 40 cm. An even greater decrease was noted with deep plowing. Both decreases are related to the greater activity of microorganisms with the deep types of plowing. During dry periods the oxidation-reduction potentials were higher at depths of 30 and 50 cm., but there was less difference among the potentials for different plowing treatments than at the 15 cm. depth. Under winter wheat the oxidation-reduction potentials measured at the 15 cm. depth were lower than under fallow (Table 3). The growth and development of the wheat root systems are related to the oxygen requirement and to a certain increase in soil density. Therefore, the oxidation-reduction potential under wheat is lower than in corresponding fallow tracts in spite of the higher moisture content of fallow soil. This explanation is confirmed by Makarov's data (3) on the carbon dioxide content of the air in the soil: under winter wheat it is 1.5 to 2 times as great as in fallow soil.

TABLE 1

Agrochemical soil indices of the experimental tract

Horizon	Depth in cm.	Total content in % of				In meq./100 gm. soil			pH		
		Humus	Nitrogen	P_2O_5	K_2O	Total adsorbed cations	Hydrolytic acidity	Exchange acidity	All in mg.	Salt extract	Water extract
A_p	0–10	1.45	0.095	0.102	0.80	6.5	4.0	0.33	1.04	4.8	5.2
"	10–22	1.66	0.106	0.117	0.56	6.3	4.3	0.23	1.08	4.7	4.9
A_2	22–34	0.52	0.029	0.093	0.25	6.8	3.5	0.31	1.49	4.5	4.9
A_2B_1	34–56	0.33	0.022	0.093	0.52	10.1	4.4	0.57	3.17	4.2	4.8
B_1	56–80	0.32	0.022	0.100	0.78	12.7	5.3	1.52	7.90	4.0	4.6

Table 4 indicates that as the soil moisture approaches the wilting point the number of microorganisms decreases and there is a significant rise in the oxidation-reduction potential of the soil. In the spring there is a noticeable decrease in the oxidation-reduction potential with ordinary plowing owing to the deterioration of soil aeration. No strict correspondence was observed between the number of microorganisms and the oxidation-reduction potential.

The changes we noted in the soil oxidation-reduction potentials during the growing season were related to the dynamics of organic matter decomposition and to a change in plant nutrient conditions. Observations of the oxidation-reduction potentials of peat-podzolic soils for two years indicated the unconditional predominance of the oxidative processes in the summer months. A decrease was noted in the oxidation-reduction potentials with soil-improvement and deep plowing. This was related to some weakening of the oxidative processes, very probably caused by the change in moisture relations, the increased activities of microorganisms and the increased respiration of plant roots.

TABLE 2

Effect of methods of deepening the plow layer on the dynamics of agrochemical soil indices

Depth in cm.		Total adsorbed cations			Hydrolytic acidity			Exchange acidity			Al		
Of plowing	Of sample taken	May 30, 1952	July 22, 1954		May 10, 1952	July 22, 1954		May 30, 1952	July 22, 1954		May 30, 1952	July 22, 1954	
			Limed	Without lime		Limed	Without lime		Limed	Without lime	In mg.	Limed	Without lime
		In meq. /100 gm. soil											
	0–10	6.5	9.6	7.6	4.0	1.9	3.7	0.33	0.02	0.16	1.0	None	1.2
	10–20	6.3	13.0	7.1	4.3	1.1	3.5	0.23	None	0.16	1.1	None	1.1
20	20–30	6.8	8.2	8.3	3.5	3.4	3.6	0.31	0.25	0.35	1.5	1.9	2.7
	30–40	10.1	10.1	10.0	4.4	3.9	4.1	0.57	0.74	0.87	3.2	5.6	7.5
	0–10	5.9	7.9	7.7	4.1	3.5	3.7	0.41	0.21	0.21	2.1	1.5	1.6
	10–20	6.1	8.2	8.5	4.1	2.7	3.8	0.38	0.06	0.19	1.7	0.3	1.4
40	20–30	6.9	7.6	9.1	3.9	4.2	3.7	0.28	0.52	0.20	0.7	4.3	1.5
	30–40	9.0	9.6	9.8	4.5	4.9	4.1	0.85	1.19	0.69	5.5	9.7	5.6
	0–10	10.2	8.5	8.4	5.1	3.7	4.2	1.14	0.29	0.76	7.2	2.2	6.2
	10–20	9.4	10.5	9.6	4.3	2.3	5.0	0.64	0.03	1.12	4.9	0.1	9.2
60	20–30	6.5	8.4	8.3	3.9	4.4	3.7	0.38	0.57	0.57	1.4	4.7	4.7
	30–40	5.8	8.4	7.1	4.2	4.3	3.9	0.28	0.93	0.36	1.3	7.6	2.9

TABLE 3

Oxidation-reduction potential of soil at a depth of 15 cm. in fallow land and under winter wheat (In millivolts with hydrogen electrode; average of three measurements)

Date determined	Plowing depth in cm.					
	20		40		60	
	Fallow	Wheat	Fallow	Wheat	Fallow	Wheat
May 12, 1954	598	405	603	568	625	550
May 21, 1954	648	535	653	548	625	573
June 9, 1954	683	650	668	633	650	628
June 23, 1954	678	667	703	655	618	670
July 7, 1954	730	705	708	668	693	678
July 22, 1954	710	675	668	660	625	635
September 16, 1954	720	635	668	665	660	—
October 10, 1954	705	660	695	665	655	580
October 27, 1954	673	647	648	655	558	570

TABLE 4

Number of microorganisms (in millions per 1 gram soil)[a], moisture and oxidation-reduction potentials of soil at a depth of 15 cm. under winter wheat

Plowing treatments	May 13			June 7		
	% moisture	Number of microorganisms	Oxid.-red. pots.	% moisture	Number of microorganisms	Oxid.-red. pots.
Ordinary	26.5	4.7	405	7.7	1.6	705
Soil improvement	26.7	4.5	568	8.1	3.8	668
Deep	26.8	5.0	550	9.8	2.1	678

[a] Number of microorganisms from the data of N. V. Meshkov.

Simultaneously with determinations of soil acidity, total adsorbed cations and oxidation-reduction potentials, observations were carried out on the dynamics of the mineral forms of nitrogen and on the mobile forms of phosphorus and potassium under the different plowing treatments. In 1953 in a fallow field, not one of nine determinations from May 22 to Oct. 27 disclosed an appreciable amount of ammonia nitrogen. A negligible amount of nitrate was observed in the spring with ordinary plowing, with plowing in some of the podzolic horizon and with soil-improvement plowing. Thus, in the upper 0 to 20 cm. horizon 11.5 to 13.8 mg. of nitrate per kg. of soil was found (Table 5). This amounted to 6.7 to 8.2 kg. of nitrogen per hectare. With deep plowing no nitrates were observed in this horizon. At the 20 to 40 cm. depth the nitrogen content per hectare was 3 to 4 kg. with all plowing treatments.

From May 22 to July 7 there was almost no rain and the transfer of nitrate from the upper horizons to the lower ones did not take place. With ordinary plowing and when some of the podzolic horizon was plowed in, the accumulation of nitrates went principally to the depth of the plow layer. There was less nitrate in the upper horizon (0 to 20 cm.) with soil-improvement plowing than with ordinary plowing while at the 20 to 40 cm. depth the amount of nitrate was two times as great. There was the least nitrate content with deep plowing, and in the upper horizon it was less than in the lower.

In July, after a protracted dry spell, the rains came and caused a considerable increase in the amount of nitrate at the 10 to 20 cm. depth and caused its transfer to a depth of 20 to 40 cm. The soil moisture increased 20 to 22%, which favorably influenced the nitrification process. From July 9 to 24 the rate of the nitrification process was at a maximum: thus, in the 0 to 40 cm. horizon there was formed on the average during a 24 hour period as much as 2.2 kg. of nitrate nitrogen per hectare with ordinary plowing, 1.5 kg. per ha. with soil-improvement plowing, and only 0.7 kg. per ha. with deep plowing.

With plowing to 20 and to 25 cm., on July 24th, in the upper (0 to 20 cm.) horizon the nitrate content was three times as great as at the 20 to 40 cm. depth. With soil-improvement plowing the amounts of nitrate in these horizons were approximately equal, while with deep plowing the nitrogen in the 20 to 40 cm. horizon was three times as abundant as in the upper horizon. July 24 may be considered as the end of the first period of accumulation of nitrates in the fallow field. From this time onward, each determination showed an increase in the amount of nitrate in the 0 to 40 cm. horizon. With the approach of the rainy period (during August and September 312 mm. of precipitation fell, totaling half of all the precipitation that fell in 1953) the nitrate in the 0 to 40 cm. horizon began to diminish. The reason for this decrease of nitrogen remained unclear: was it only because of leaching of the nitrates or did a retardation take place in the nitrification process because of the excess soil moisture so that the process of biological absorption exceeded the process of nitrate accumulation?

If the amount of nitrate nitrogen leached from the upper 40 cm. horizon during the months of August, September and October is calculated, we obtain for control plowing 87 kg. of nitrogen per hectare. When some of the podzolic horizon is plowed in, 57 kg. is leached. With soil-improvement plowing the figure is 76 kg. and with deep plowing, 71 kg. In this calculation the nitrogen from applied fertilizer was included in the balance, while the absorption of nitrate by microorganisms was not considered. Keeping in mind that these calculations are conditional and assuming that the actual loss of nitrates from the 40 cm. horizon exceeded the indicated amount, we noted that in a rainy period like that of August to October 1953, the greater amount of nitrates which had accumulated in the fallow field was washed down deeper than 40 cm.

TABLE 5

Dynamics of nitrates in a fallow field

Date	Plowing depth in cm.	NO_3 in mg. per kg. of soil at the following depths		N in kg./ha. in layer	Remarks
		0–20 cm.	20–40 cm.	0–40 cm.	
May 22, 1953	20	13.8	7.2	12.9	
	25	12.5	4.8	10.2	
	40	11.5	6.4	10.8	
	60	None	6.0	3.9	
July 9, 1953	20	71.8	12.4	50.1	
	25	57.2	16.4	45.8	
	40	50.6	37.8	53.3	
	60	21.3	29.7	32.3	
July 24, 1953	20	102.1	33.7	83.5	July 10, 3 metric tons/ha. lime applied
	25	77.0	23.9	62.8	
	40	58.9	60.7	75.3	
	60	16.5	48.6	43.0	
August 8, 1953	20	91.2	42.9	82.8	July 25, 45 kg. K_2O and 30 kg. P_2O_5 applied
	25	97.3	36.0	83.0	
	40	59.4	51.0	66.8	August 5, 30 kg. N
	60	17.5	27.1	33.3	
August 28, 1953	20	67.7	33.0	60.8	August 22, seeded with winter wheat
	25	66.3	41.2	66.9	
	40	63.8	39.3	62.5	
	60	22.3	25.6	31.3	
September 12, 1953	20	73.2	51.5	82.4	
	25	56.9	46.5	65.0	
	40	67.9	48.0	70.0	
	60	20.8	54.3	51.8	
October 27, 1953	20	20.5	30.0	31.2	
	25	7.3	13.1	13.2	
	40	5.2	8.4	12.9	
	60	4.2	6.9	5.7	

In the autumn the wheat used 22 to 30% of the nitrates which were in the 40 cm. soil horizon on September 12, 1953. Continued observation of nitrification under winter wheat in 1954 showed the following: on tracts where spring fertilizing was not carried out in the 0 to 40 cm. layer of soil plowed by the different modifications, 9 to 10 kg. of nitrogen per hectare was found at the beginning of May. That is, the amount is close to that left in this horizon at the beginning of

TABLE 6

Yield of winter wheat (in centners per hectare) with liming (1954)

Plowing depth in cm.	General fertilizer P_{15} (granulated superphosphate in narrow bands)					
	$N_{30}K_{45}$	P_{30} K_{45}	$N_{30}P_{30}K_{45}$	$N_{60}P_{30}K_{45}$	$N_{60}P_{30}$	Control
	Treatment					
	1	2	3	4	5	6
20	17.5	19.1	21.1	21.3	21.9	14.6
25	18.2	19.2	19.9	23.4	20.6	16.2
40	20.6	20.8	21.4	25.9	22.1	18.1
60	15.0	15.9	19.6	21.3	18.6	13.7

Note: Phosphorus and potassium fertilizers applied under double fallow in this experiment in two ways; in fertilization treatment 4 and 5, 30 kg. nitrate nitrogen was applied under cultivator tillage; in fertilization treatments, 3, 4, and 5, 30 kg. of nitrogen was applied in spring during the growing season. Mean experimental error m = ±1.6 centner.

winter. But after a month under winter wheat, both on tracts fertilized with 30 kg. of nitrate nitrogen and on non-fertilized tracts, only 0.3 to 1.6 kg. of nitrate nitrogen per hectare was left. By the wheat harvest (July 22) the amount of nitrates in the soil had increased slightly to 3.7 to 4.6 kg. of nitrogen per hectare. At this date the fallow tracts which had been left among the wheat sowings and which had received 30 kg. of nitrogen per ha., contained 49 kg. per ha. of nitrate nitrogen with ordinary plowing, 46 with deep plowing, and 58 with soil-improvement plowing. After the wheat harvest and continuing up to the late fall very little nitrate was found under mixed grasses in their first year. Thus, the greatest amount of nitrate nitrogen (6 kg. per ha.) was seen with ordinary plowing.

In 1954 it was very dry until the middle of August. This situation was reflected in the nitrification processes in the fallow tracts. Until the middle of August the nitrate content in these tracts was smaller than in the fallow fields in 1953. This year in the fields with deep and soil-improvement plowing we observed a slackening of the nitrification processes at the 20 to 40 cm. depth. A sharp rise in the nitrification process in fallow fields was noted at the end of August and the beginning of September, when the rate of nitrification with ordinary plowing was 3.2 kg. of nitrogen per hectare per day, with soil-improvement plowing 2.5, and with deep plowing 1.8. The intensified nitrification can be explained by favorable meteorological conditions. By September 9, 113 kg. per ha. of nitrate nitrogen had accumulated in the 0 to 40 cm. horizon as a result of the nitrification process with ordinary plowing, 90 with soil-improvement plowing and 77 with deep plowing. In the preceding year up to this date the soil nitrate content was 1.5 to 2 times as small because it had been leached from the horizon and located deeper than 40 cm.

According to Maslov (4), in fallow fields of the peat-podzolic zone, nitrate nitrogen accumulates at the rate of 60 to 90 kg. per hectare. That is, the quantity of nitrogen is near our figures. It should be noted that the great amount of nitrate in the upper horizon with ordinary plowing corresponded to a higher oxidation-reduction potential at the 15 cm. depth.

Table 6 shows the winter wheat crops by individual plowing treatments and applied fertilizer. It is evident from the table that the nitrate nitrogen which accumulated in a fallow field was insufficient for optimum development of wheat when phosphorus and potassium fertilizers were applied (compare the two treatments using $P_{30}K_{45}$ and $N_{60}P_{30}K_{45}$).

Nitrogen, applied as ammonium nitrate at the rate of 30 kg. of N per hectare in the fall and to the growing crop at 30 kg. of N per hectare in the spring, gave the greatest increase in the grain crop—5.4 centners per hectare with deep and 5.1 with soil-improvement plowing. When the podzolic horizon was plowed in, the additional yield of wheat was 4.2 centners per hectare, but with ordinary plowing it was 2.2. Upon comparing the fertilizer treatments, it was evident that with plowing in of the podzolic horizon and soil improvement and deep plowing, an increase in the crop was produced by nitrogen applied in the fall, that is, on just those plowing treatments in which extensive leaching of nitrates into the lower horizons takes place in the fall (see Table 5).

Analysis of the above-ground parts of the wheat indicated that with ordinary plowing and with fertilizing at $N_{60}P_{45}K_{45}$, 60 kg. of nitrogen per hectare accumulated in the plants but fertilizing with $P_{45}K_{45}$ yielded only 42 kg. of nitrogen per hectare in the plants. The corresponding figures for these two fertilizing rates with soil-improvement plowing were 81 and 52 kg. of nitrogen per hectare and with deep plowing 57 and 32 kg. nitrogen per hectare.

Two years' observations of the changes in available phosphorus showed that the amount does not remain constant during the growing season but changes in all horizons and plowing treatments. During the dry periods of the year, when the soil moisture was lowered to the wilting point, the acid-soluble phosphorus content of the soil showed a tendency to decrease. Toward fall with the onset of the wet period, the amount of available phosphorus in the soil increased.

In 1953 the phosphorus was determined by A. T. Kirsanov's method in the 0.2*N* hydrochloric acid extract, and in 1954 by F. V. Chirikov's method in the 0.5*N* acetic acid extract. Colorometric determinations were made by E. Truog's method with a photocolorimeter. The change to the acetic acid extract method was made both because of general considerations and because, with deep plowing, many insoluble phosphates of the sesquioxides from the soil samples of the upper horizons went into solution in the hydrochloric extract. They did not have the positive action of phosphate fertilizers on the yield of oats with this plowing treatment.

The largest quantity of phosphorus was extracted by hydrochloric acid from soil which had been subjected to deep plowing, somewhat less from soil with soil-improvement plowing and the least with ordinary plowing (Table 7). When wheat was sown, the most phosphorus was extracted by acetic acid from soil given ordinary plowing. With soil improvement and deep plowing the content of phosphorus was similar. In fallow tracts the most phosphorus was present with deep plowing (here its content was higher than under a crop). The next highest amount was with ordinary plowing and the smallest amount of available phosphorus was noted with soil-improvement plowing. In contrast to deep plowing, with ordinary and soil-improvement plowing the amount of available phosphorus in the fallow tracts was considerably less (3.7 and 2.1 mg. of P_2O_5 per 100 gm. soil) than under a crop where there were 6.6 and 4.7 mg., respectively. We attribute this to the increased solubility of calcium phosphorus under the influence of the CO_2 accumulating in the soil air under a crop.

TABLE 7

Content of mobile phosphorus in soil by treatments of plowing in 1953 and 1954

Plowing depth in cm.	P_2O_5 in mg. per 100 gm. soil by depth					
	0–10	10–20	20–30	30–40	0–20	20–40
In 0.2*N* hydrochloric acid extract (1953)						
20 (fallow)	6.7	6.3	5.6	5.1	6.5	5.3
40 “	8.1	7.3	7.9	8.5	7.7	8.1
60 “	9.7	9.6	6.7	7.6	9.6	7.0
In 0.5*N* acetic-acid extract (1954)						
20 (crop)	8.4	4.9	3.4	2.1	6.6	2.7
(fallow)	4.0	3.4	3.0	2.6	3.7	2.8
40 (crop)	5.1	4.2	2.8	2.1	4.7	2.5
(fallow)	2.5	1.8	1.7	1.3	2.1	1.5
60 (crop)	3.9	2.9	4.7	2.3	3.4	3.5
(fallow)	4.4	5.3	4.1	4.4	4.8	4.2

The largest crop increase from phosphorus, 4.6 centners per hectare of grain, (see Table 6) was obtained with deep plowing; with ordinary plowing the increase was 3.6 centners per hectare, with plowing in of the podzolic horizon and with soil-improvement plowing the increases were considerably less, 1.7 and 0.8 centners per hectare, respectively, which is within the limits of the experimental error.

Analysis of the plants indicated that, for its development, the wheat utilized a comparatively small amount of phosphorus, from 15 to 19 kg. of P_2O_5 per hectare. The action of the 30 kg. of superphosphate P_2O_5 as the basic fertilizer increased the wheat yield, regardless of the application of 15 kg. P_2O_5 in rows at sowing. This can be explained both by the small amount of acetic acid-soluble phosphorus with these plowing treatments (3.4 to 6.6 mg. of P_2O_5) and by the fact that the spring and summer were very dry so that the superphosphate applied in rows remained in the dry layer of the soil and was difficult to assimilate.

Exchangeable potassium was determined by flame photometer with a 1*N* ammonium acetate extract from soil to solution proportion of 1:10.

From the literature it is known that the potassium of the clay soil fraction is the most mobile and available to plants. From this we infer that with soil-improvement and deep plowing, by means of which the percentage content of the clay fraction in the upper horizons is increased in comparison with ordinary plowing, the potassium nutrition of the plants will be more favorable. Observations of the exchangeable po-

TABLE 8

Average content of exchangeable potassium in soil during growing season, by plowing treatments

Plowing depth in cm.	K_2O in mg. per 100 gm. soil by depth (cm.)						K_2O in kg./ha. by depth (cm.)		
	0–10	10–20	20–30	30–40	0–20	20–40	0–20	20–40	0–40
From May 24 to Oct. 27, 1953									
20 (fallow)	11.3	11.1	10.0	12.5	11.2	11.2	293	326	619
25 "	11.0	10.8	9.6	12.0	10.9	10.8	289	308	597
40 "	9.8	10.4	9.7	11.8	10.1	10.8	260	308	568
60 "	11.5	13.2	10.4	10.9	12.3	10.7	355	307	662
From May 9 to Oct. 20, 1954									
20 (crop)	9.4	7.8	7.6	11.0	8.6	9.3	234	252	486
(fallow)	10.0	8.8	8.1	10.7	9.4	9.4	255	255	510
40 (crop)	9.4	8.4	9.7	12.5	8.9	11.1	247	306	553
(fallow)	9.6	9.0	9.6	10.7	9.3	10.1	258	279	537
60 (crop)	9.2	9.1	9.1	9.3	9.1	9.2	247	254	501
(fallow)	8.8	9.3	7.9	8.0	9.0	8.0	244	220	464

tassium content in the genetic horizons of the soils studied, averaged for the 1953 growing season, showed that there was less in the podzolic and the transitional horizons (10.0 mg. K_2O per 100 gm. soil, Table 8) and more in the illuvial (12.5 mg.). In the plow layer the potassium content was 11.2 mg., amounting to only about 1.25% of the total soil potassium.

On the average during the 1953 season, the 40 cm. layer of soil contained the least exchangeable potassium with soil-improvement plowing (568 kg. per ha. K_2O); next (597 kg. per ha.) in potassium content was soil plowed 25 cm. deep; then, ordinary plowing (619 kg. per ha.); the largest quantity of potassium (662 kg. per ha.) was found with deep plowing, with most of it in the upper 20 cm. horizon.

Observations on the dynamics of exchangeable potassium showed that the absolute amount of potassium during the growing season changes, but its relative distribution by horizons remains about the same as noted in Table 8. Thus, in our experiment during the period when the soil moisture dropped 7.7 to 8.3% (June 24) the amount of potassium was reduced from 12.7–11.5 to 10.7–9.4 mg. K_2O per 100 gm. of soil. It can be assumed that this decrease in exchangeable potassium in the soil occurred because of its fixation by soil colloids. When the soil moisture had risen to 21 to 24% (July 24th) the amount of exchangeable potassium was significantly increased in all horizons and plowing treatments (from 9.4–9.9 to 11.6–13.7 mg. K_2O per 100 gm. of soil). This increase in the exchangeable potassium content of the soil coincided with the increased development of microorganisms at this time and with the greatest accumulation of nitrate in the fallow field. It would be incorrect to explain this increased amount of exchangeable potassium only by the physical-chemical state of the soil colloids. Activation of the microbiological life and the related accelerated decomposition and mineralization of organic matter also made possible the potassium conversion into more mobile forms. During the period of heavy rains, when the moisture of the soil exceeded the field capacity, a considerable translocation of potassium from the upper soil horizon to the lower was noted. The possibility of large losses of potassium from the soil in wet years was shown in the work of Vil'gusevich (1), but 1954 was very dry. Until the second half of August the soil moisture remained at a low level. Exchangeable potassium in this year—both that under wheat crops and that under fallow fields—was less than in 1953 (Table 8).

Examining the action of potassium fertilizer (potassium chloride) on the yield of winter wheat by plowing treatments (see Table 6), and keeping in mind Kirsanov's statement (2) that with a content of 7 to 8 mg. of exchangeable potassium per 100 gm. of soil, the plants can utilize only 15 to 20% of this amount, we see that of the apparently large quantities of exchangeable potassium determined in our experiment—230 to 250 kg. per hectare in the 20 cm. horizon—only 50 kg. per ha. was converted into potassium which the plants can utilize.

Analysis of the yield showed that for the formation of its above-ground portion up to the spike stage, winter wheat made use of 71 kg. per ha. K_2O with ordinary plowing, 86 with soil-improvement and 62 with deep plowing. Hence the action of 45 kg. of potassium on the yield of winter wheat is clear. The crop increase with soil-improvement plowing was 3.8 centners per hectare, and with deep plowing and plowing in of the podzolic horizon it was 2.7 and 2.8 centners per hectare. The residual effect of potassium chloride was evident in the yield of hay in this same experiment. The hay crop with potassium chloride fertilizer was from 10 to 15 centners per hectare greater than without potassium.

Conclusions

1. The deepening of the plow layer in peat-podzolic soil by plowing in some of the podzolic horizon and by soil-improvement plowing does not cause any substantial change in the total adsorbed cations or the soil acidity. Deep plowing causes increases in the upper 20 cm. layer of the total adsorbed cations, the acidity, and the content of mobile aluminum, the amount of which decreases only after liming. The soil oxidation-reduction potential decreases as the depth of plowing increases.

2. The amount of nitrate nitrogen accumulating in the 0 to 40 cm. horizon of a fallow field as a result of deepening the surface soil decreases systematically with increasing depth of plowing. Thus, if with ordinary plowing the amount of accumulated nitrate nitrogen reached 105 to 113 kg. per ha. in the experiment, then 83 to 90 kg. per ha. accumulated with soil-improvement plowing, but it was more evenly distributed in the 0 to 40 cm. horizon. With deep plowing the nitrogen accumulation was 65 to 77 kg. per ha. Nitrification process takes place more actively in the surface horizon as the interval after deep plowing becomes longer, while in the deeper horizons nitrification is inhibited.

3. The amount of available phosphorus (extracted by acetic acid) under wheat crops was greatest with ordinary plowing and least with plowing to 60 cm. (deep plowing).

4. The amount of potassium assimilated by plants does not change materially when the plow layer is deepened. The content of exchangeable potassium in the soil increases with an increase in the soil moisture.

5. The highest yields of wheat are obtained with soil-improvement plowing with liming. This is related to the large volume of soil utilized by the plant root system and to better moisture conditions.

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SOIL INVESTIGATION METHODS ON STATE FARMS ORGANIZED ON VIRGIN SOIL[1]

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To intensify land reclamation and to make organization plans for state farms organized on virgin and overgrown lands, a soil survey should be made on a scale of 1:25,000. At this scale it is possible to establish the basic patterns of the relation between soil types and definite plant groups and elements of the terrain.

Our investigations of the soils of the Western Caspian Foreland, the Volga-Akhtubinsk flood plain and a number of state farms on virgin land show that 1:25,000 aerial photographs, if available, allow us to distinguish soil contours with the accuracy of a scale of 1:10,000. In particular cases the deviation in drawing contour boundaries may vary by only tenths of a millimeter. Such accuracy in delineating soil contours on aerial photographs makes it unnecessary to use smaller scales. It is also possible to increase the area characterized by a soil section or a half-pit in soil surveys by a minimum of one third or more. The explanation for this increase is that the soil boundaries are not distinguished by the number and location of sampling pits and spoil heaps, but on the basis of a change in the shades of color on the aerial photographs. Soil survey experience shows that in the study of the soil cover of different types it is expedient to sink only half-pits to determine the basic genetic horizons of one or another of the soil types. Deep soil sections should be taken less often in the survey and only to determine the depth of the water table, salt horizons, parent material and also to select soil samples and rock for analysis. On the basis of work in the field, then in the office, we compile the soil map, a basic document serving as the solution to many problems. This is the reason we consider it a mistake to replace it with agronomic soil maps showing only the agronomic soil groups. Agronomic soil groups usually include a number of soils, and most often show the boundaries of different complexes and combinations. By some of the interim directives, these are assigned by some authors to one group, but by other authors to other groups. Agronomic soil maps, which do not give the borders of the soil types, are difficult and sometimes impossible to use in the compilation of the large-scale survey maps required by scientific institutions and for planning.

However, we must add that the soil study only from the point of view of geographic distribution, and presenting the investigation results in the form of a soil map still does not give a complete conception of the measures for increasing soil fertility and for producing constant high yields. It is necessary to carry out more profound studies of the soil properties and in particular to determine the content of nutrients and other indices—the content of humus and of adsorbed cations, the distribution of salts in the soil profile, and so forth. All this permits evaluation of the soil cover from the point of view of production and designation of the ways in which it is to be used and cultivated. In this connection we recommend the compilation of a number of maps and cartograms to solve various questions both in carrying out land use projects and in compiling organization plans and other data of a directive nature to define the trend of the economy and its development in the next few years and into the future.

As an example we will cite map diagrams of the V. R. Williams State Grain Farm, Oktyabrskoy district, Kustanayskaya region. On this soil map (not shown), 33 soil-types are distinguished containing different combinations of soil types, differentiated by their physicochemical indices. All agricultural practices and radical improvements must consider the specific characteristics of each type. Depending on the relative abundance of certain soil types they can all be combined into seven agricultural productivity groups (Fig. 1). The first such group is composed of soil areas in which meadow-granular and meadow-chestnut soils predominate with distinctively fine texture (clay loam and clay) and high humus content which, in the surface

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[1] The information contained in this article was presented in 1956 at a meeting of the Department of Soil Science of Moscow State University and at a special conference of the Soil Reclamation Division, Ministry of State Farms, USSR.

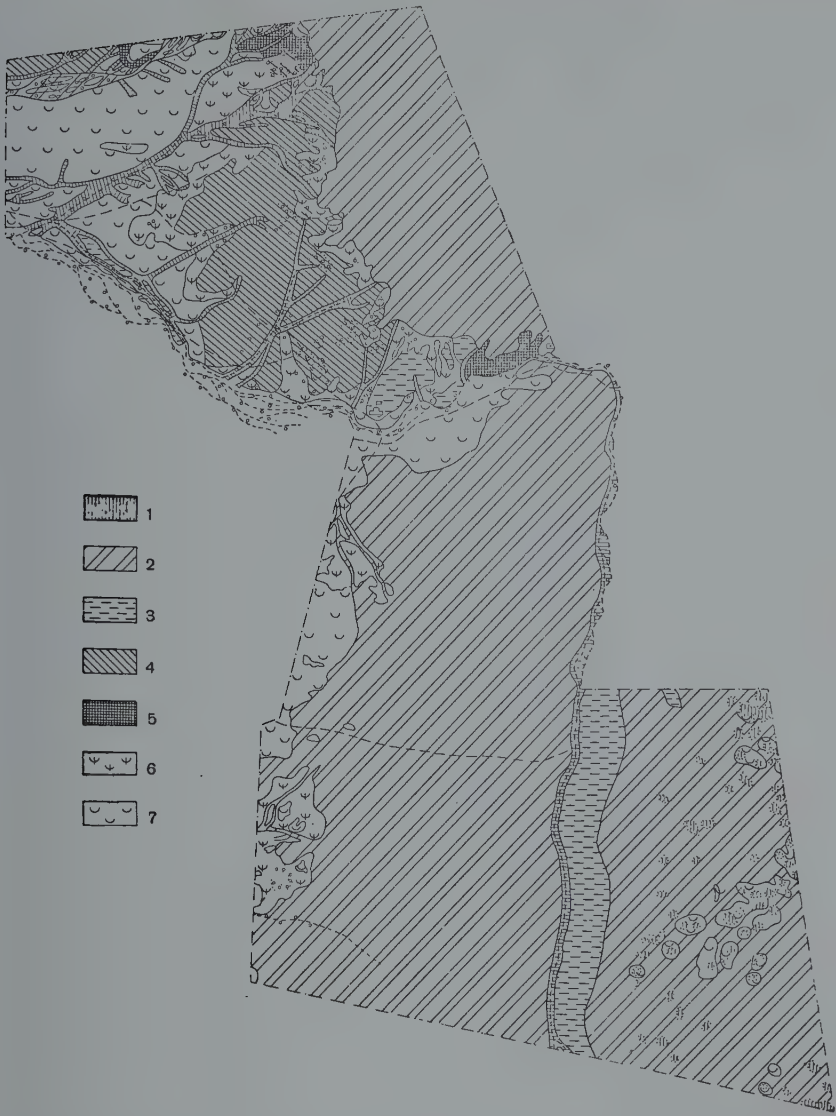

FIG. 1—Classification of the soils of the V. R. Williams State Farm into agricultural productivity groups. 1—Meadow granular and meadow-chestnut soils complexed with dark-chestnut soils; 2—dark-chestnut soils combined with meadow-chestnut and meadow-granular soils; 3—dark-chestnut soils in combination with dark-chestnut soils having varying degrees of water erosion and with meadow-chestnut soils; 4—meadow-chestnut, meadow-granular, meadow-residual solodized, and peat-podzolic soils complexed with up to 25% of solonetzes; 5—meadow-chestnut and dark-chestnut soils complexed with up to 50% of solonetzes; 6—primary soils on outcroppings of original rock complexed with up to 75% of crusty medium- and deep-columnar solonetzes; 7—flooded, external, medium-columnar solonchak-type solonetzes and solonchaks.

soil, varies from 3 to 9% (that is, it is several times as large as that of the zonal soils). As one would expect from the amount of humus in these soils they contain a lot of nitrogen but only negligible amounts in hydrolyzed form. In all the meadow soils there is extremely little available phosphorus and potassium. Therefore the application of phosphate and potassium fertilizers could exert a positive influence on crops. These soils are saturated generally with calcium and magnesium. Other cations do not play any substantial part in their physicochemical properties. These soils, occurring in the form of irregular isolated spots among the zonal dark-chestnut soils cause nonuniformity for tillage purposes and variations in time of crop ripening, leading to the abrupt and harmful development of field irregularity.

The second agricultural productivity group includes soils which are basically dark chestnut in combination with soils which have been eroded to a varying degree. This productivity group of soils is the most widespread. It constitutes most of the state farm land area being used under grain sowings. All the dark-chestnut soils, including the eroded types, are distinguished by fine texture (clay-loam). Humus content varies within fairly wide limits—from tenths of a per cent in the severely eroded types to 4% in the noneroded dark-chestnut soils. The humus content reaches 9% in the upper horizons of the meadows, soils, stream valleys and small gullies.

The dark-chestnut soils, especially their eroded types, are poor in nutrients, primarily nitrogen and phosphorus. The latter is mostly combined with calcium in difficultly soluble forms which are abundant in these soils. The next specific characteristic of this productivity group is the presence in the profile of easily soluble salts—chlorides and sulfates—and, in the deeper horizons there is an increase in the amount of alkali. In the upper horizons, on the other hand, the alkaline cations represent an insignificant percentage of the total. This may indirectly show the absence of solonetz formation in these soils. In the strongly eroded types the easily soluble salts are close to the surface and on some steep slopes they exude.

The third productivity group includes a number of soil areas where in addition to dark-chestnut and meadow soils, about 20% of soils are subjected to water erosion, that is, more eroded soil than in the second group. Control of water erosion, particularly of terraces and sodded strips is therefore needed. In general this group of soils is suitable for plowing and the passage of tractors and, like the soils of the second group, may be used for sowing grains.

The fourth agricultural productivity group consists of soils having thin genetic horizons entering into the composition of the plow layer. Thus, for example, in a number of soil areas solonetzes are found in which horizon A varies from 5 to 18 cm. in thickness. Horizon $A + B_1$ has a total thickness of 15 to 35 cm. Other soil areas of this productivity group (weakly developed, meadow-residual solodized and podzolized on original rock, and various solonetzes) also have an A_1 horizon of negligible thickness but of which the plow layer may be formed. Horizon A_1 is usually underlain by eluvium, distinguished by its poor physical and chemical properties. As a result of an extremely small amount of humus the eluvium, when wetted by water, slakes into primary particles which, cohering on drying out, form a thick, solid crust. Crust forms also by the alkaline reaction of the soil solution. To improve the physical and chemical properties and the soil fertility of this productivity group, it must be sowed with mixed grasses for a number of years.

The fifth agricultural productivity group consists of solonchaks and solonetzes. Other soils constitute less than a third of the area, but data from water extracts show that they contain a large amount of easily soluble salts. It is expedient to use areas of such soils for pasture. The existence in this productivity group of chestnut, meadow and other soils puts it in the category of better pasture. In wet years like 1956 sowings of various crops on solonetzes develop normally and produce large harvests.

The sixth agricultural productivity group has a higher percentage of solonetzes than the preceding, but the last productivity group, the seventh, consists entirely of crusty takyr-like (eroded) and medium-columnar solonetzes with easily soluble salts located near the surface. Further, these solonetzes are distinguished by high alkalinity, low humus content and extremely poor physical properties. These specific characteristics have caused poor natural vegetation acclimatization in areas of the last two productivity groups. Tracts occupied by their soils are suitable only for use as rotating pasture.

On the basis of the preceding agricultural-productivity soil groupings, we propose the following plan for the use of the area of the state farm (Fig. 2).

I. The large southeastern part of the state farm (to the east of the Marka-Say stream) is represented generally by dark-chestnut soils, but spots of meadow soils are scattered on this general background, while in the eastern part of this large area these spots (either in groups or singly) are fringed by a fairly broad belt of crusty-columnar and medium-columnar solonetzes. This is plainly represented on the diagrammatic map of the land utilization recommendations for the state farm. We recommend dividing into separated fields the tracts on which spots of meadow soils are fringed to the greatest extent by solonetzes, as planned on the diagrammatic map. The remaining good-sized portion of the large area should be sown with different crop rotations usual for this region, including corn. Thus, crop rotation No. 1 and two separated fields are located on this large area.

II. The large area located opposite the first one on the other side of the Marka-Say contains soils of the second agricultural productivity group, as does another large area with the same soils in the eastern part of the northern half of the state farm. It is planned to divert these to crop rotation No. 2, generally with grain crops.

III. The middle part of the northern half of the farm is considered desirable for conversion to crop rotation No. 3, for growing fodder crops in general, with sowings of annual and perennial grasses. The area of this crop rotation is composed chiefly of soils of the fourth productivity group, distinguished by their thin genetic horizons and poor physical properties. In addition, the northeastern part of this crop rotation area includes soils of the second group, having the most level terrain. The southern part includes soils of the third and fifth groups. For growing grain crops, soils of this crop rotation area are much less suitable than those of the areas of Nos. 1 and 2 crop rotations. Most cases will require a specific approach to such crops, both with respect to tillage and to crop selection.

The soils of the fourth productivity group, generally weakly developed, are suitable for use under perennial grasses and annuals (that is, sorghum). In cultivating these soils it is desirable gradually to increase the thickness of the plow layer with the simultaneous application of organic fertilizers and to use periodic deep subsoiling. The soils of the fifth productivity group —the saline series—are little suited for growing grasses and even less for grains until they are cultivated. Therefore, it is better to use them for pasture during the first period of reclamation. Successful use was recently made of two-layer plowing for cultivating solonetzes. While the plow layer is left in place, horizon B_1 is plowed into a greater depth. Deep subsoiling is also necessary here since by disturbing the soil's natural structure, it increases permeability and creates conditions for the development of the percolation of moisture and the leaching of salts from the upper horizons. The gradual desalinization of solonetzes will make possible subsequent cultivation on them not only of grasses, but other fodder crop rotations.

Soils of the second and third groups, scattered over the whole large fodder crop rotation area, are suitable for sowing any crops, but because of their susceptibility to erosion they require special anti-erosion measures.

IV. Soils of the meadow and partly of the eroded dark-chestnut types and solonetzes are located at various places in a belt of varying width along the Marka-Say stream. The stands of grass here are good. It is expedient to use these soils for hay and vegetables, although they are suitable in every way for grain crops.

V. Soils of the sixth and seventh productivity groups—dark chestnut with a high proportion of solonetzes—are not suitable at present for any crops and should be used for pasture.

VI. On the northern half of the farm, between crop rotation areas Nos. 2 and 3, we have delineated an area consisting chiefly of primary, weakly developed soils which are partly forested and, in our opinion, suitable for continuous forests and conversion to pasture. Within the farm boundary there are many other areas (steep slopes) which are strongly subject to erosion and on which trees should be planted.

On the basis of available scientific and production experience we give the following recommendations on this question: For planting on rocky soils, juniper is recommended, and on shaded slopes, Tian-shan mountain ash and *Ulmus pamila* (4). On the meadow-bog and meadow-granular soils encountered in spots on this soil area will be placed plantings of aspen, birch, willow and black poplar. The most suitable types for solonetzes would be *Ulmus foliacea* Gilib., tamarisk, and Turkestan elm. Partial af-

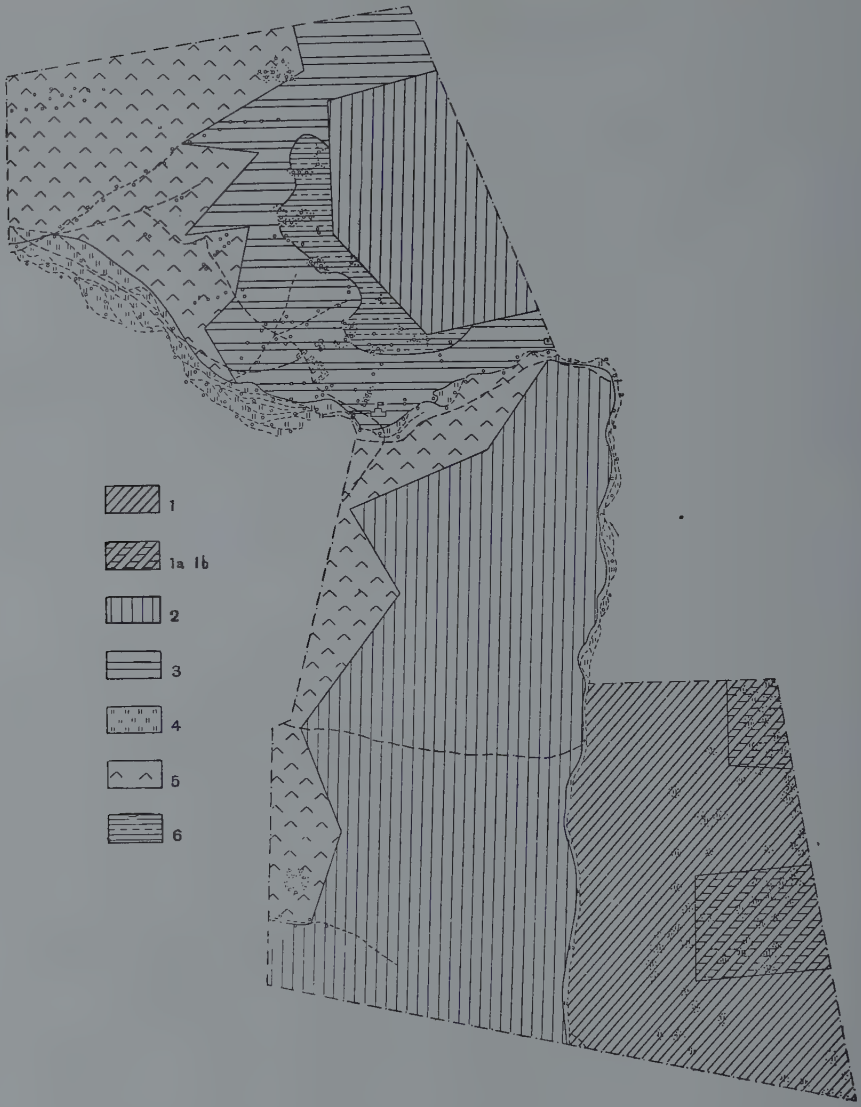

FIG. 2—Map diagram of recommended land uses for the area of the V. R. Williams State Farm. 1—Crop rotation area No. 1 with two separated fields. The general crop rotation area is used for grains, including corn. 1a and 1b—Separate interspersed fields assigned for the sowing of mixed grasses; 2—Crop rotation area No. 2 with the usual selection of grains; 3—Crop rotation area No. 3: fodder with sowings of annual and perennial grasses; 4—Lands adjoining the Marka-Say stream: used for hayfields or selected vegetables and melons; 5—Area occupied by soils of the fifth, sixth and seventh agricultural productivity groups, used generally for pasture; 6—Area converted to pasture and afforested.

forestation should also be carried out on the loamy-sandy meadow-residual solodized and peat-podzolic soils on bare spots between clumps of birch, for which pine and Siberian larch are recommended.

In crop rotation areas Nos. 2 and 3 at the dark-chestnut soil boundaries on strongly eroded steep slopes, further erosion should be avoided by planting or sowing spirea, and if the appropriate seedlings are available it is expedient to plant some steep slopes with *Ulmus pamila*, Tian-shan mountain ash and Schrenk's spruce (4, 3).

In addition to the steep slopes requiring afforestation, these areas also have slopes which, although not steep, show pronounced traces of erosion. These are mostly eastern and western slopes. To stop erosion it is necessary (and sufficient) to use interspersed strips of perennial grasses across the slopes. In addition, it is recommended that deep subsoiling be carried out in the fall. This will make possible greater assimilation of the surface moisture which is ordinarily lost to runoff and which usually takes with it particles of topsoil. Necessary plowing and basic tillage generally should be carried out across the slopes.

The farm's surface relief assures a good runoff of the snowmelt via numerous hollows and gullies into Marka-Say creek, flowing through the farm. This water must be prevented from escaping by creating ponds and reservoirs, which may be accomplished by extremely simple methods—building earth dams. To make these artificial ponds and reservoirs last longer, water-saving shelterbelts should be planted around them, using mostly fast-growing trees which react well to moist soil: willow, aspen, birch and black, balsam and hybrid poplar.

Growing Field Shelterbelts. In arid steppe regions one of the most important conditions for producing steady crops is the presence of shelterbelts. This is shown by data accumulated over a period of many years by scientific research institutes and the abundant experience of state and collective farms both in Kazakhstan and in other regions having climate and soil conditions similar to those of Kazakhstan.

Shelterbelts improve the moisture relations of the air and the soil and protect the fields from hot, dry winds, from having the seedings blown away and from drifting of the land during the violent dust storms usual in Kazakhstan. Only in the presence of shelterbelts can there be normal development of perennial grasses, a very important component of crop rotations in grassland agriculture. "In the absence of shelterbelts the practical agricultural effectiveness of grassland agriculture sinks to such low value that it cannot serve as a basis for the introduction of grasses into the crop rotation" (V. R. Williams). This attitude is fully applicable to the conditions found in the arid districts of Kustanayskaya region.

In conclusion we give the following two plans for the arrangement of types of trees in shelterbelts as recommended by Sherlin (1, 4) for the dark-chestnut soils of Western Kazakhstan:

First plan

1st row: Golden currant
2nd " Green ash and Russian elm
3rd " (same)
4th " Oak and Siberian acacia
5th " (same)
6th " (same)
7th " (same)
8th " Green ash and Russian elm
9th " (same)
10th " Golden currant

Second plan

1st row: Ground cherry
2nd " Smooth-leaf elm and box elder
3rd " (same)
4th " European white birch and Siberian acacia
5th " (same)
6th " (same)
7th " (same)
8th " Smooth-leaf elm and box elder
9th " (same)
10th " Ground cherry

In place of currants and cherries it is possible to plant *Amelanchier canadensis* Med. which gives tasty berries and is conspicuously frost-resistant.

Snow Retention. Under arid steppe conditions snow retention must be included among the most important agricultural practices directly accumulating moisture in the soil. Only two methods of snow retention are of practical importance at present in the steppe regions of Kazakhstan—tractor snowplows and snow retention strips. We think that use could be made of one more method for retaining snow by surface treatment: packing the snow by broad, heavy rollers or by inclined smoothing implements having a broad, heavy sliding surface. We do not know if this method is used in any cases in large-scale agriculture (it is used on aerodromes). Our recommendation is based on theoretical considerations and personal investigations in winter on the Kazakhstan steppes. The strong winter winds lift and blow away loose snow, but packed snow does not blow away. On sunny days, particularly at the end of winter, catastrophically rapid evaporation of the loose snow takes place. But in spring, packed snow is retained on the land considerably longer than loose snow, and for this reason the gradually formed snowmelt is better absorbed by the soil. Those who live on the steppe know how long packed snow remains on the access roads when the surrounding fields have long since been freed of it. Levelling implements and rollers for packing the snow are recommended for experimental use.

Use has long been made in Kazakhstan of snow retention strips and snowplows to retain snow. Corn, sunflower, sorghum, mustard, safflower and sudangrass were considered the best plants for snow-retaining strips, though sunflower and Indian mustard have proved to be the best in practice.

Soil Tillage. The Kazakh Branch of the V. I. Lenin All-Union Academy of Agricultural Sciences (VASKhNIL) gives a complete and well-founded group of *agricultural technical methods* assuring the production of spring wheat crops and others which are as high as possible under the conditions in Kazakhstan. These methods are supplemented with some remarks concerning the specific characteristics of the soil cover of the Williams State Farm.

On the Williams State Farm and on the state farms which will eventually adjoin it, along with the reclamation of all arable virgin soil, perennial grasses must be included in the field and fodder crop rotations with annual fodder crops. In the last analysis it takes as much care to grow perennial grasses as it does to grow grains. There are numerous experimental and production data on the positive significance of perennial grasses in forming the structure and increasing the fertility of the *all zonal soils* (2). Grasses are being successfully grown in Kazakhstan, especially in Kustanayskaya region. The Kazakhstan Institute of Agriculture (3) has produced convincing data for four triennial periods on the effect of the grass system of agriculture on grain crops. The Institute also gives well-founded recommendations for agricultural practices to grow perennial grasses on dark-chestnut soils. They cover grass mixtures, rates and methods of sowing, pre-sowing treatment of the seeds, care of the sowings, times and methods of harvesting, and drying the harvested crop. Of the annual grasses, sorghum, the "camel of the plant kingdom," comes in for a good deal of attention. Chinese sugar cane (*Sorghum saccharatum*) is distinguished by its drought resistance and also for its responsiveness to precipitation, its tolerance of soil conditions (it can grow on saline soils), especially valuable for the state farm being discussed here since it has many dark-chestnut solonetz soils as well as solonetzes and solonchaks. Sorghum is valuable and nutritious cattle feed and the juice of the stalk contains up to 17.4% of sugar when the seeds are at the stage of milky ripeness. The agricultural cropping practices are given in the account of this state farm.

Questions of Fertilizer. On the basis of a chemical analysis of soils from the state farm one might think that the crops would react well to the application of phosphorus and potassium fertilizers, in physiologically acid forms, to the basic dark-chestnut soils. But the questions of the rates, times and methods of applying them on various crops requires a special experimental solution. We think that the application of fertilizers to virgin lands at this stage of their reclamation is not of primary importance. The chief problem now is to control drought by applying the measures presented above: planting trees, constructing reservoirs, snow retention and correct agricultural practices with respect to tillage, selection of crops and varieties, and so forth.

We have given a description of the soils and information on the soil-forming rock, climate, vegetation and other natural factors exerting some influence on the development of local agriculture. In addition to a soil map, we have given 1) a map diagram of the recommended land use of the area of the farm; 2) a map diagram of the agricultural productivity groupings of the soils of the farm and 3) a map diagram of the forest improvement measures. It is obvious that on other state farms under different soil and climatic conditions, a need may develop for cartographic representation of other meas-

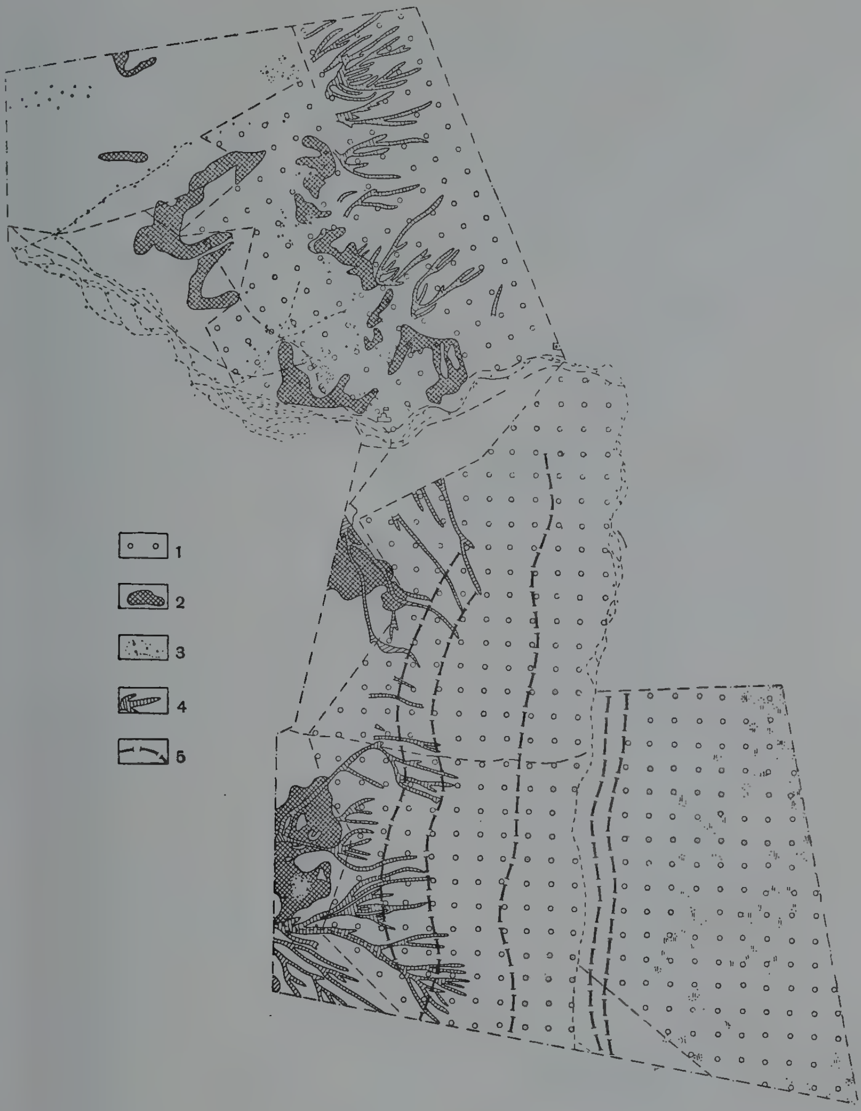

Fig. 3—Map of the forest improvement measures for controlling erosion of the soils of the area of the V. R. Williams State Farm, Oktyabr'skoy district, Kustanayskaya region. 1—Shelterbelts on crop rotation areas 1, 2 and 3; 2—Continuous afforestation of the soils in which juniper is planted on rocky soils; aspen, birch and willow are planted on spots of meadow-bog and meadow-granular soils; and smooth-leafed elm and tamarisk are planted on solonetzes; 3—Partial afforestation with pine; 4—Spirea plantings (sowings) on crop rotation areas 2 and 3 and on strongly eroded steep slopes; 5—Erosion control measures.

A—On crop rotation areas 1 and 2 on slopes facing east and west grass strips should be used across the slopes with deep Mal'tsev-type subsoiling in the fall.

B—On the same crop rotation areas, including the slopes, snow retention measures are to be used with snow packing by rollers.

ures which are very important for them, that is map diagrams of liming, fertilizing, drainage or irrigation, or of salinity, depth of the water table, and so forth. Using the Williams State Farm as an example we have tried to find a method of soil investigation allowing the most expedient use of the large labor requirement and giving the production worker the most practical weapon in his honorable struggle for big harvests and for increased fertility of the lands of these vast virgin regions.

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HIGH-MOUNTAIN SOILS OF THE EASTERN SAYANS

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In vast areas of the high-mountainous plateau of the Eastern Sayans, at absolute altitudes of 2000 to 2700 meters, peculiar soils are found which we have tentatively called "sod gol'tsov soils." These soils have developed in a landscape of dry mountain tundra, with a predominance of lichens in the soil vegetative cover (several species of *Alectoria, Cladonia alpestris, Cetraria cucculata*). There are conspicuous amounts of Dryadaceae, cobresia, sedges, crowberries, gentian and dicranum mosses. Landscapes of such dry mountain tundra are characteristic of boreal mountainous regions with abrupt continental climate.

The climate of the Eastern Sayans is characterized by a negative mean annual temperature of −4.6° C., a short hot summer (to +35° C.), a dry, very cold winter (down to −50° C.) and low annual precipitation (260 to 280 mm.). During the year, there is an abrupt summer maximum (June–August) of precipitation in the course of which about 85% of the annual precipitation takes place (data collected by the Orlik Station, 1258 meters absolute altitude).

In the literature, only Petrov (2) describes sod gol'tsov soils of the central and northern sections of the Eastern Sayans, which he calls "cinnamon-brown tundra soils." They are also widely distributed in the mountainous regions of Eastern Siberia. Investigations of recent years in the Trans-Baikal and at Yakutiya have shown similar soils in the mountain ranges of Barguzinsk, Ikatsk, North and South Muysk, and at Verkhoyansk. Their presence may be expected in all mid-continental mountainous regions of Eastern Siberia which are capable of having mountain-tundra zones, owing to their absolute altitude. Data presented by American investigators (3) show the wide distribution of similar plant associations and soils in the mountains of Alaska (in the interior sections, as well as along the coast). According to the investigators, these soils form the background of the mountain ranges of Alaska, and are called "arctic brown soils." The name "sod-gol'tsov soils" proposed by us does not seem fully satisfactory, but it is more suitable since the sod-forming process is most clearly expressed and is predominant in these soils, and the term "gol'tsov" relates these soils to the dry, stony high mountains of Eastern Siberia, which have received the well-known name of "gol'tsov."

Thus, "gol'tsov soils" have a wide and definite area of geographical distribution.

Characteristics of Sod Gol'tsov Soils

Sod gol'tsov soils have a characteristic brownish to cinnamon color throughout their profile. At greater depths, the color becomes lighter and sometimes acquires a yellowish hue. We present a morphological description of sod gol'tsov soils.

		Profile 37. Mt. Khodarus Absolute altitude 2580 meters. Quartz diorite formation. Various forms of frost activity—basins, troughs. Vegetation—reindeer moss, sedges, some mosses.
A	0 to 12 cm.	Coarse sandy loam, dark-gray with cinnamon-brownish hues, roots and plant residues. Dioritic gravel. Comparatively abrupt change to the following horizon.
AB	12 to 43 cm.	Loamy sand, dark cinnamon brown with browinsh hues, roots, dioritic gravel. Comparatively abrupt transition.
B	43 to 60 cm.	Brownish loamy sand. Abundant gravel. Transition gradual.
BC	60 to 90 cm.	Gravel (1 to 10 cm.) almost without particles <1 mm. diameter.

In the 0 to 60 cm. horizons the under side of the gravel has iron incrustations. The parent material is quartz diorite of the following mineralogical composition: plagioclase 33; orthoclase 9, quartz 8, biotite 25, epidote 15; titanite 5; chlorite 5%. (The mineralogical analysis was performed by the senior scientific associate at the Geological Institute, Academy of Sciences, USSR, V. P. Y-Eremeyev.)

The top horizon A, 12 to 18 cm. thick, has sometimes grayish, but more often bright brown hues, and contains 6 to 7% humus (Table 1). The lower part of the profile has more of a cinnamon-brown color. The humus content sharply decreases with depth, but the extent of the humus profile is nevertheless large—about

TABLE 1

Physicochemical characteristics of a sod gol'tsov soil, profile 37

Depth cm.	Hygroscopic water, %	pH		Humus, % (Tyurin)	Adsorbed cations In me. (Gedroits)			Adsorption capacity, me.	Unsaturation, %	Fe, mg./100 gm. (Kirasnov)	Fe, mg./100 gm. (Tamm)	Exchange Acidity, mg./100 gm. (Sokolov)		
		Water extract	Saline extract		Ca^{++}	Mg^{++}	H^+					$Al^{+++} + H^+$	Al^{+++}	H^+
0–5	2.38	5.06	4.47	6.52	1.8	2.7	2.5	7.0	36	1	276	2.7	2.7	0.0
											198	0.3	0.3	0.0
15–20	1.31	4.85	4.65	1.69	1.7	3.2	0.6	5.5	11	4	209	0.0	0.0	0.0
45–50	1.31	5.34	4.65	0.95	1.3	3.2	0.0	4.5	0	5				

1% humus is still found at 50 cm. depth. These soils are acid. The pH of the water extract is about 5.0, and at greater depths the reaction changes very little (pH of water extract, 5.3). The humus horizon has an adsorption capacity of 7 to 8 me.; the lower horizons, of 4 to 5 me. The exchange acidity of the top horizon is considerable, but the unsaturation amounts to 35 to 40%. Acidity is due to aluminum, even in the humus horizon. At depth 12 to 18 cm., the exchange acidity is zero. Evidently the acid reaction of the soil is due mainly to acid organic matter. A small increase in the adsorption capacity of the top horizon takes place at the expense of local increase in the humus content, that is, at the expense of organic colloids. The clay fraction content also increases somewhat in the upper horizon (Table 2). Texture of the top horizon is sandy loam; all the remaining parts of the profile are loamy sand. The profile is rich in gravel (20 to 200 mm.).

All this is evidence of only slight weathering of the soil's mineral mass. Great dryness of the air and low temperatures obviously slow down markedly the processes of chemical weathering. We observed that in more humid regions of the high-mountain Eastern Sayans (especially in the zone adjoining the Munku-Sardyk range on the north), on the same parent material and at the same altitudes, the soil was more clayey. Evidently, in the bare rock zone it is dryness that inhibits the processes of chemical weathering to a greater degree than low temperatures do.

A high content of adsorbed Mg is observed in these soils. The amount of Mg equals or even surpasses the amount of adsorbed Ca. This phenomenon is often observed in the mountain-taiga and mountain-tundra soils of the Trans-Baikal. With reference to its distribution throughout the profile, iron (mobile and total) clearly shows a tendency to accumulate at the superficial horizons of the soil (up to 300 mg. per 100 g. of soil by the Tamm procedure, and 4.20% total). This phenomenon of iron accumulation toward the surface in various degrees is characteristic of all tundra soils of Eastern Sayan, and is linked to the absence in summer of a deep leaching of sesquioxides and to a migration of iron to the frozen surface horizons of the soil in autumn and winter (1).

Total Al_2O_3 also shows a maximum at the upper horizon (Table 3). Total CaO and MgO are fairly stable throughout the whole profile. As a whole, total analysis shows weak activity of the leaching processes and stability or accumulation of iron in the surface horizons.

According to its fractional composition, the humus of sod gol'tsov soils differs significantly from mountain-taiga soils, the humus of which is characterized by a high content of fulvic acids. (Table 4). In the humus of sod gol'tsov soils, humic acids predominate, and among them the

TABLE 2

Texture of a sod gol'tsov soil, profile 37

Depth, cm.	Loss on treatment with HCl	Diameter of particles, mm.					
		1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	0.001
0–5	4.90	32.60	34.08	11.85	3.32	8.00	5.25
15–20	3.56	34.00	36.43	14.90	3.93	4.00	3.18

TABLE 3

Abridged total analysis of a sod gol'tsov soil (in % of the absolutely dry sample), profile 37

Depth, cm.	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	CaO	MgO	Loss on ignition
0–5	62.20	22.60	18.40	4.20	3.52	1.29	10.00
15–20	69.30	19.44	15.39	4.05	3.54	1.99	4.35
45–50	69.50	21.20	18.17	3.03	3.54	1.25	3.33

TABLE 4

Fractional composition of the humus of a sod gol'tsov soil, profile 37

Depth, cm.	Fulvic Acids					Humic Acids				Non-hydrolyzable residue		Total humus in % (Tyurin)
	1a	1	2 + 3	Total	% of total humus	1	2 + 3	Total	% of total humus	%	% of total humus	
0–5	0.42	0.92	0.46	1.81	27	1.86	1.23	3.09	47	1.62	16	6.52
15–20	0.30	0.00	0.00	0.30	18	0.14	0.34	0.48	28	1.20	46	1.69
45–50	0.20	0.06	0.29	0.29	—	Not det'd	0.00	None	—	0.66	—	0.95

acid fraction which is extractable by direct treatment with alkali (that is, the humic acids which are simplest in structure and the most mobile). The humic acid content is almost twice as great as the fulvic acid content.

Such a peculiar composition of the humus is explained, obviously, by the following causes: 1. Lichens, which form the greater part of the plant leaf fall, contain substances capable of forming the most mobile humic acids, passing directly into the alkaline extract. 2. Greater molecular complexity of the humic acids formed is prevented by unfavorable conditions.

Attention is called to the small adsorption capacity of the humus horizon in the presence of a significant amount of humus. The organic matter of sod gol'tsov soils has a low adsorption capacity—about 110 to 150 me. per 100 g. (as compared to the normal value of about 400 me. per 100 g.). Probably, in spite of considerable organic matter decomposition, this has nevertheless another, more coarsely dispersed character. Humic acids are sharply limited to the upper horizon; that is, to the area where the humification of organic residues goes on directly. Somewhat below, at depths of 12 to 18 cm., the humic acid content remains equal to the fulvic acid content. At still lower horizons only fulvic acids penetrate.

It must be noted that the mountain-tundra zone of the Eastern Sayans is not uniform and has a vertical spread of 2000 to 2700 meters. In the lower part of the zone, at altitudes of 2000 to 2300 meters, a subzone of mountain-tundra shrubs has developed. It is represented by shrub birch, creeping willows and golden rhododendron, with a predominance of lichens in the soil vegetative cover, but mosses (Dicranum, Phtilidium) are substantially represented. Here the conditions are more humid than in the higher subzone of lichen tundra, devoid of a shrub layer. The shrubs favor retention of the snow blanket and collect the snow blown by constant strong winds away from the higher open spaces of lichen tundra. Owing to this, in the spring the snowmelt creates in the shrub subzone a condition of excess humidity which is seasonal and of short duration, but which is capable of developing the marks of a weak gleization in the soil.

We present a morphological description of a gleyey humic sod gol'tsov soil of the shrub tundra.

Profile 38. Absolute altitude 2150 meters. N.W. 8—degree slope from Mt. Khodarus toward Peretolchin volcano. Dwarf birches, two species of willow, rhododendron. Two species of lichens, mosses, dwarf crowberry, bog bilberry.

A 0 to 9 cm. Sandy loam, dark gray with a cinnamon-browninsh hue. The upper two to three cm. are almost black, and consist of slightly decomposed plant residues. Pierced by roots. Has diorite gravel (20–200 mm.). Transition comparatively abrupt.

AB 9 to 25 cm. Brownish loamy sand, with infrequent dark blue spots. Fewer roots. The gravel has iron coatings. Transition comparatively abrupt.

B_1 25 to 57 cm. Light brownish loamy sand with dark blue spots, fine grit and diorite gravel with iron coatings. Transition gradual.

B_2 57 to 70 cm. Light colored loamy sand with greenish hues in the parent material. Isolated roots.

Parent material: quartz diorite with the following mineralogical composition: plagioclase 65, quartz 10, biotite 20, epidote 5%. (Mineralogical analysis by V. P. Y-Eremeyev.)

TABLE 5

Physicochemical characteristics of a gley humus sod gol'tsov soil, profile 38

Depth cm.	Hygroscopic moisture, %	pH		Humus, %	Adsorbed cations, me.			Adsorption capacity, me.	Unsaturation, %	Fe, mg./100 gm. (Kirsanov)	Fe, mg./100 gm. (Tamm)	Exchange acidity mg./100 gm. (Sokolov)		
		Water extract	Saline extract		Ca^{++}	Mg^{++}	H^+					$Al^{+++} + H^+$	Al^{+++}	H^+
0–8	3.80	4.65	3.71	29.80	5.3	1.4	9.0	15.8	57	20	300	9.9	9.9	0.0
13–18	0.98	5.11	4.47	2.39	1.3	2.1	0.9	4.4	21	15	259	0.7	0.7	0.0
35–40	0.28	5.51	4.77	0.69	2.5	2.2	0.0	4.7	0.0	9	194	0.0	0.0	0.0
65–70	0.26	5.77	4.61	0.58	1.7	2.3	0.0	4.0	0.0	20	170	0.0	0.0	0.0

TABLE 6

Fractional composition of the humus of a gley humic sod gol'tsov soil, profile 38

Depth cm.	Fulvic Acids					Humic acids				Non-hydrolyzable residue		% total humus (Tyurin)
	1a	1	2 + 3	Total	% of total humus	1	2 + 3	Total	% of total humus	%	% of total humus	
0–8	0.97	2.348	1.42	4.73	15	2.34	3.18	5.52	18	19.55	56	29.80
13–18	0.53	0.295	0.088	0.91	38	0.14	0.32	0.46	19	1.02	35	2.39
35–40	0.100	0.020	0.128	0.25	36	0.00	0.00	0.00	0.00	0.44	—	0.69
65–70	0.075	0.020	0.107	0.20	34	0.00	0.00	0.00	0.00	0.38	—	0.58

As seen from the morphological description and the analytical data, the differences between gley humic sod gol'tsov soils and sod soils consist in a weaker peat formation in the upper 2 to 3 cm. of the profile, little change in the composition of the humus in the sense of an increase in the fulvic acid content and light gleization (Tables 5 and 6). A change in the humus composition favors, evidently, besides a higher humidity, a somewhat different composition of the litter, which in the shrub subzone consists chiefly of dead leaves and twigs of the underbrush. Residues of dead mosses and lichens usually decompose very rapidly; in contrast with this, we found litter of the previous year almost undecomposed on the surface. The leaves had become only slightly brown. The slowly decomposing litter of the shrubs probably constitutes one cause of high acidity of the organic matter in the shrub subzone. Essentially soils of the shrub and lichen subzones are very similar in character and in the conditions of the soil-forming processes. They represent two variants—dry and more humid—of the same soil type.

Conclusions

1. In the mountain-tundra zone of the Eastern Sayans, both typical and also humic gleyey varieties of sod gol'tsov soils have developed. Sod gol'tsov soils do not have exactly the same features distinguishing all tundra soils of plains and mountainous regions which have as yet been described in the literature, that is, markedly excessive humidity and thick sod-formation in the upper horizon.

Peculiarities of typical sod gol'tsov soils are:

a. Dryness of the profile (or absence of excessive moisture).

b. Acid reaction throughout the whole profile (pH of the water extract about 5.0).

c. A considerable humus content (6 to 8%) with much decomposition of organic matter; downward extension of the humus profile; preponderance of humic acids over fulvic acids (almost double); among the humic acids that fraction is predominant which is directly extractable by alkaline solution.

d. Considerable amount of iron (mobile and total) in the profile; processes of migration of iron to the surface horizons of the soil.

e. Geographical correlation of these soils with

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the dry mountain-tundra zones of abruptly continental mountainous regions of the boreal belt.

2. Specific peculiarities of sod gol'tsov soils and the definite geographical area of their distribution make it necessary to place these soils as an independent group.

3. With respect to economics, such mountain tundras are valuable reindeer pasture which at present are utilized almost not at all in agriculture.

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TEMPERATURE RELATIONS IN LIGHT-CHESTNUT YERGENI CLAY LOAM IN FIELDS AND UNDER A SHELTERBELT

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Tree plantings on light-chestnut soils meet with great growth difficulties, resulting mainly from insufficient soil moisture. Because of long water deficiency the woody vegetation ages rapidly, grows poorly, and dies early.

Forest plantings exert a considerable influence on the area they occupy, thereby improving their own growing conditions. The change in soil temperature relations play a large role in this and also effect changes in the water relations, the amount of moisture which evaporates uselessly, the rate of drying the root layer of the soil and the extent to which the soil is wetted in spring.

The effect of the soil temperature on its water relations has long been studied. Lebedev (5) proved experimentally that soil moisture migrates as vapor from a layer with a higher temperature into one with a lower temperature. Dolgov (2) writes, "Although the total amount of water vapor does not exceed 0.001% of the weight of the soil, it plays an enormous role in the redistribution of water in the soil, in the loss of its reserves through evaporation and in part in its accumulation through condensation from the atmosphere."

We were interested in the change in soil temperature relations caused by shelterbelts up to 20 m. wide to aid in preliminary recommendations for providing extra water for growing trees in a shelterbelt.

Forest plantings in the steppe change the temperature relations of the soil because the tree canopy allows only a small part of the solar radiation through to warm the soil. According to the data of Kostin (4), in a 43-year-old oak plantation in the Voronezh region on a clear June day, the tree crowns hold back about 90% of the solar energy. Using a light meter to measure the intensity of the July light in the shelterbelts of an experimental tract, we found that an oak plantation held back 85 to 90% of the solar energy while a white acacia plantation held back only 69%.

We determined the soil temperatures from 1951 to 1954 on experimental shelterbelts on the Zavetin tract, located on the western slope of the Yergeni plateau (47° 17′ N., 43° 53′ E.). The climate of this region is sharply continental with cold winters and hot summers. The mean annual air temperature is 8.5° C.; the absolute maximum in the past 20 years, 42.6° C., was observed in August, while the absolute minimum, −35° C, was observed in February. The soil surface temperature in summer sometimes reaches 60° C. The mean annual precipitation somewhat exceeds 300 mm. The soil is predominantly a light-chestnut clay loam, while the parent material is a loess-like silt loam. Ground water was not located over a large part of the tract even though borings extended to 40 m. The soil temperature was measured in shelterbelt No. 2, consisting of oak and shrubs planted in 1932; it was 20 m. wide and 4 to 5 m. high. The density of the canopy (including both trees and shrubs) was 0.5 to 0.6. Simultaneously, the soil temperature was measured in a grain field.

Temperatures were measured at depths of 0.5, 1, 1.5, 2, 2.5, 3, 3.5 and 4 m. by a vacuum thermometer placed at the bottom of a boring made by a soil auger to the appropriate depth. We did not measure the temperatures at any particular time, since the soil temperature does not change during the day at depths greater than 0.5 m. However, measurements at the surface were always made at 1:00 P.M.

Of the two years when most of our data was gathered, 1952 was noted for its cool summer and warm winter, while 1953, on the other hand, had a hot summer and a freezing winter. The data obtained from soil temperature measurements in the field are shown in Fig. 1 as temperature isopleths.

The temperature relations in the soil are characterized on the one hand by a change during the course of the year and on the other by a change with depth. The greatest amplitude of temperature change during the year is at the

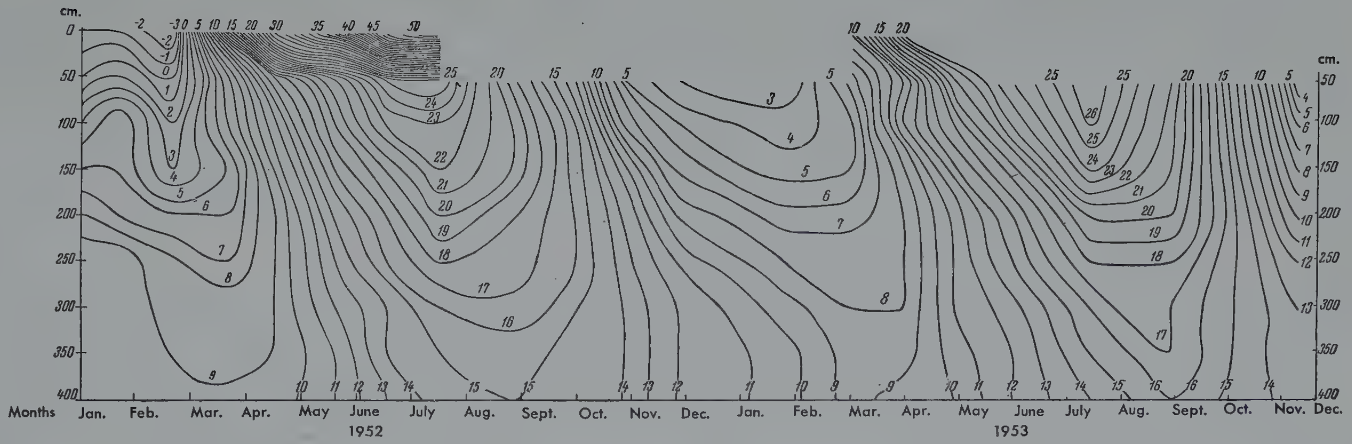

Fig. 1.—Soil temperature isopleths in a field on the Zavetin tract of experimental shelterbelts.

soil surface. According to our data it varied in 1952 and 1953 from −3° C. in March to +52° C. in August on the experimental tract fields. Its amplitude would undoubtedly have been somewhat higher if the winter temperature of the soil surface had been measured at night. At the 50 cm. depth the soil temperature decreases sharply and during the year varies from 0° C. to 27° C.; the maximum here, as on the surface, occurs in August, and the minimum is reached in March. With increasing depth the maximum temperature decreases and the minimum increases, so that the annual amplitude of the temperature range becomes smaller; and the times of occurrence of the maxima and minima gradually shift to a later date.

At the 100 cm. depth the maximum temperature is 26° C. and the minimum 2° C.; the respective figures for 150 cm. are 24° C. and 3° C.; for 200 cm., 20° C. and 5° C.; for 250 cm., 18° C. and 5° C.; for 300 cm., 17° C. and 6° C.; for 350 cm., 17° C. and 7° C.; and for 400 cm., 16° C. and 8° C.

The date of the maximum temperature shifted from August, for the 50 cm. depth, to September for the 400 cm. depth, while the minimum similarly shifted from March to April.

The effect of hot summer weather and cold winter weather on soil temperature is manifested down to a depth of 4 m. and evidently even deeper.

Considering the direction of soil moisture movement in vapor form in connection with the temperature distribution, the data obtained shows the summer type of temperature distribution, in which the temperature decreases with depth, extends in April to a depth of 150 to 200 cm., in May from 200 to 400 cm., and in June, July and August to more than 400 cm. In years with hot summers, such as 1953, this temperature distribution is maintained to a depth of 4 m. into September. In years with a cool summer one may observe in September the separation of two layers with different types of temperature distribution—one from 150 to 400 cm. with the summer type and the other from 0 to 100 cm. with the winter type. In October the dividing line between them goes down to a depth of 200 cm. In November, December, January, February and March the winter type of temperature distribution takes in the entire four-meter stratum of the parent material studied.

It is obvious that the movement of soil water vapor should go in different directions during the course of the year. It can be assumed that in June, July and August and, in hot years, in September too, the water vapor moves downward to the four-meter level and deeper, while in November, December, January, February and March its movement is in the opposite direction. In April and May the water vapor should flow toward the 150 to 350 cm. level both from above and from below, but in October and, in cool years, in September, it should move both upwards and downwards away from the 50 to 250 cm. layer. In general terms these are the soil temperature relations in the field and the directions of vapor movement in soil.

The rate of water vapor movement and, consequently, of the drying or moistening of any soil layer increases with an increase in the temperature gradient. The magnitude of the gradient is also reflected in the rate of movement in the same direction of the soil moisture in liquid form (3).

These data show that the magnitude of the soil temperature gradient in the field changes both in the course of the year and also with depth. In this respect the top half-meter layer of the soil, where the summer temperature gradient reaches a high value, differs from the deeper layers in which the gradient always remains low.

In winter during the daytime we found a small gradient for the upper 50 cm. layer of the soil—2° C. to 3° C.; it doubtless reaches higher values at night. But if there is even a thin layer of snow the soil temperature variations between day and night are evened. With the transition from winter to summer the value of the temperature gradient in this layer increases constantly and reaches a maximum in August; in March it is 3° C. at 50 cm.; in April, 10° C.; in May, 15° C.; in June, 17° C.; in July, 23° C.; and in August, 25° C. These data apply to the daytime temperatures, during the period of the greatest warming of the soil surface. At night the temperature gradient may fall to zero. In the 50 to 100 cm. layer the temperature gradient over these 50 cm. varies from 4° C. to 0.5° C. during the course of the year. The gradient becomes increasingly smaller, with simultaneous decreases in amplitude, as the depth increases. Thus, in the 100 to 150 cm. layer the gradient is 3.5° C. to 0.5° C.; from 150 to 200 it is 3° C. to 0.5° C.; from 200 to 250 it is 3° C. to 0° C.; from 250 to 300 cm. it is 2° C. to 0° C.; from 300 to 350 cm. it is 2° C. to 0° C. and from 350 to 400 cm. it is 1° C. to 0.5° C.

For practical reasons there is great interest in the quantitative determination of soil moisture movement as vapor under these concrete conditions, but we are not in a position to do this. Morozov (6) determined that when the gradient was 1° per cm., the mean temperature was 24° and when the soil moisture was at the hygroscopic coefficient, the loss of water in vapor form was 2.18 mm. per 24 hours. If the rate of water vapor movement is directly proportional to the temperature gradient, then in the soils we investigated the rate would in most cases be about 0.1 mm. per 24 hours and could increase to as much as 1 mm. only in the top half-meter layer of the soil on summer days.

Consequently, the effect of the temperature relations on the water relations under these conditions may be manifested in the more rapid drying out of the topmost soil horizons. This has a negative effect on the growth of the grassy vegetation with small roots. With respect to the moistening of the soil root zone by the winter movement of the soil moisture in vapor form, such moisture can hardly exceed 15 to 20 mm. during the season. Fedoseyev (8) came to the same conclusion.

We now go on to analyze the soil temperature relations in shelterbelts. The data obtained by temperature measurements in shelterbelt No. 2 are shown in Fig. 2 as temperature isopleths.

In the shelterbelt, as in the fields, the largest temperature change during the year takes place in the soil surface—from 0° C. during the winter to 33° C. in summer. This amplitude may even be increased somewhat by lower temperatures in winters with little snow and by higher temperatures in summers with drier and hotter weather than in 1952. At the 50 cm. depth the temperature decreases abruptly in summer and varies during the year from 1° C. to 23° C. The amplitude of the yearly fluctuation in soil temperature decreases continuously with depth. Thus, at a depth of 100 cm. it changes within limits of 2° C. to 22 °C., at 150 cm. from 3.5° C. to 19° C., at 200 cm. from 5.5° C. to 17° C., at 250 from 6° C. to 16° C., at 300 cm. from 7° C. to 15° C., at 350 cm. from 8° C. to 14° C. and at 400 cm. from 8° C. to 13.5° C. The beginning of minimum temperatures is somewhat delayed in proportion to depth and shifts from March (at the surface) to April (at the four-meter depth), while the maximum temperature shifts from August to September.

The summer type of temperature distribution in April takes in the layer of soil from the surface to a depth of 150 cm.; in May it extends down to 250 cm., in June to 350 cm. and in July and August it goes down to 400 cm. and deeper. After a winter with little snow and much frost the beginning of the summer type of distribution is somewhat delayed, and a hot, dry summer delays the transition to the winter type. Deep wetting of the soil in the shelterbelts with snowmelt from drifts first cools it, but then, as a result of the increased thermal conductivity of moist soil, hastens its warming. For this reason increased soil moisture is not reflected in the time when the summer type of temperature distribution begins.

The winter type of temperature distribution includes November, December, January and February and, in some years, March. In October, the maximum temperature is at a fairly superficial depth which is shallower than the maximum of the winter type of distribution but deeper than that of the summer type.

The temperature gradients in winter are smaller at all depths of the soil profile. During the warm period of the year, from April to September, they are increased, but only in the top half-meter layer; below this they remain low. In the upper half-meter layer the temperature gradient across the 50 cm. varies during the course of the year from 2° C. to 15° C.; from 50 to 100 cm. from 0° C. to 3° C.; from 100 to 150 cm., from 0° C. to 4° C.; from 150 to 200 cm., from 0° C. to 4° C.; from 200 to 250 cm., from 0° C. to 2° C.; from 250 to 300 cm., from 0° C. to 3° C.; from 300 to 350 cm., from 0° C. to 2° C.; and from 350 to 400 cm., from 0° C. to 1.5° C.

The effect of the shelterbelt on the soil temperature, according to our data, is manifested in lower maximum temperatures and higher minimum temperatures than in the fields. The maximum temperatures are subject to a greater change (3° C. to 4° C.) than the minimums (1° C.); an especially wide difference in maximum temperatures is observed in the soil surface layer, where it may reach 20° C. This is evidence of the greater effect of the shading by the forest canopy compared to the warming action of the blanket of snow. In April, when

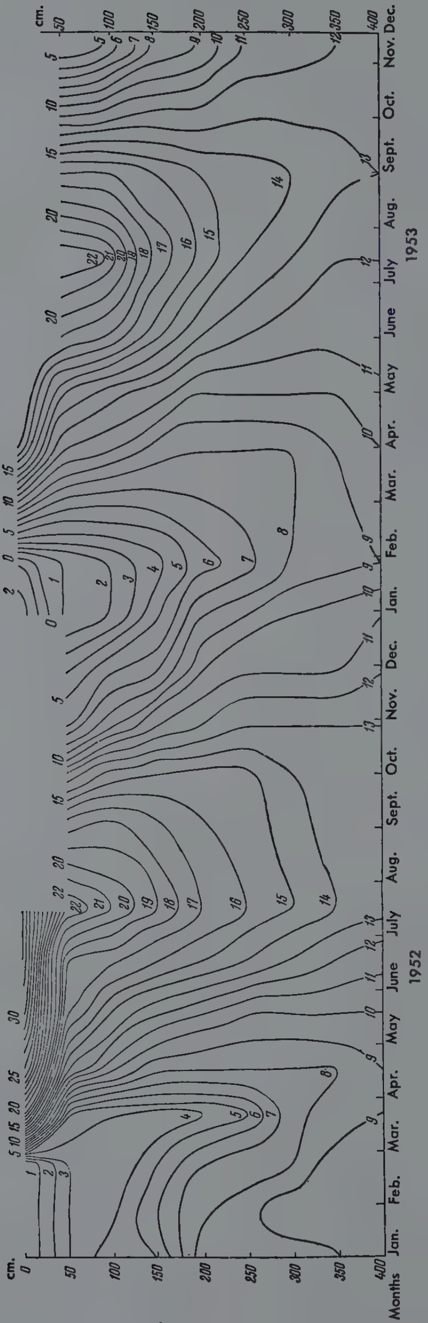

FIG. 2.—Soil temperature isopleths in a shelterbelt on the Zavetin tract of experimental shelterbelts.

there are as yet no leaves on the trees but there is a high degree of insulation, the soil temperature in the shelterbelt is usually higher than in the fields, but only in the upper horizons.

The effect of the shelterbelt on the soil temperature can be detected down to 4 m. and is manifested in a 2.5° C. decrease in the maximum temperature and a 0.5° C. increase in the minimum. However, there is no qualitative change in the soil temperature relations under the shelterbelt. There is no material difference in the maxima and minima either in the fields or in the shelterbelt during the course of the year or with change in depth. The distribution of temperature according to the summer and winter types remains identical. Because of this the temperature conditions under the shelterbelt do not cause any changes in the water relations of the soil. Certain negligible deviations in the distribution of the maxima and minima took place only in March and April under the influence of abundant soil moisture from the snowmelt of the drifts.

The effect of shelterbelts on the soil temperature decreases with depth and for this reason the temperature gradients under them are somewhat less than in the fields: consequently there is a decrease in the movement rate of the soil moisture.

According to the data in the literature, tree plantations change the water relations of steppe soils, increasing their moisture and raising the water table. One of the factors making this possible is the change in temperature relations caused by the shading action of the forest canopy. Thus, for example, Denisov (1) attributes the cause of a rise in the water table at Velikiy Anadol to the condensation of water vapor in the C horizon, cooled by the forest canopy. This assumption may be proved only by special observations on the temperature relations. As far as the Zavetin Experimental Tract is concerned (as we saw above) shade does not play a material part in increasing the soil moisture under the shelterbelts. A temperature distribution favorable to the intensive movement of soil moisture occurs only in the upper half-meter layer of the soil during those months (June, July and August) when its moisture decreases to the hygroscopic coefficient.

If moistening of the shelterbelt root zone takes place in winter as a result of the downward movement of water vapor from the parent material, its primary cause is not the change in temperature relations under the shelterbelt, but is the snowdrifts, the water from which when thawed penetrates to 4 m. and deeper and remains there until winter.

The failure of the root zone of the forest to become moistened in winter because of the water vapor movement from below upward has also been established by Pavlovskiy (7) for the Moscow area. He explains it by the fact that the temperature differences are less pronounced in the forest than in the fields and by the fact that trees dry the soil to greater depths.

Apparently the only favorable aspect of the shade provided by the shelterbelt is the decrease in evaporation from the soil surface. Because of it the amount of moisture used by the woody vegetation is somewhat increased. Quantitatively this would amount to about 20 mm., considering that evaporation dries out only a 20 cm. layer of soil (5).

Conclusions

1. The woody vegetation of shelterbelt plantations on the light-chestnut soils of the Yergeni plateau changes the temperature of the soil: it becomes lower in summer and higher in winter.

The most extreme changes in temperature take place in the upper half-meter layer of the soil during the daytime in June, July and August, when the difference in temperature between fields and shelterbelts reaches 20° C. In the deeper layers of the parent material this difference decreases to 1° C. to 4 °C.

2. The effect of a shelterbelt 20 meters wide on the temperature extends deeper than 4 m.

3. Exerting their effect on the temperature relations of the soil, the woody plants of the shelterbelt make possible a decrease in the energy of moisture movement in vapor form.

4. The change in the soil temperature relations under the effect of forest canopy shading cannot increase the intake of moisture into the root zone of the shelterbelt. Evidently the only favorable effect of the summer cooling action by the forest canopy is to decrease evaporation; this may result in saving 20 mm. of water during the season.

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SALINIZATION OF SOILS IN THE AZOV IRRIGATION SYSTEM AREA, ROSTOV REGION

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THE first large-scale irrigation work in Rostov region was in the area of the Azov irrigation system. The source of the water is the Veselyy reservoir (on the Manych river) water from which reached the Veselyy canal in 1951 and the Azov canal in 1952. In the eastern part of this area observations have been made since 1951 on the condition of the ground water and soils. This paper presents the results of observations on soil changes with irrigation.

The area described is located on the second terrace of the Manych river at the head of the Azov irrigation system near the Veselyy reservoir. Its total area is about 8,500 hectares. On the north it is bounded by the Manych river, on the south by the Azov canal from which the water comes to irrigate its southern portion, and on the west by Bagayevsk district. The Veselyy canal proceeds along the area from the Veselyy reservoir (Fig. 1); the water from this canal irrigates the northern part of the area.

On the level surface of the terrace are the raised riverside ridge along the Manych, a small ridge in the southwest part of the area, three small wooded former streambeds of the Manych (the Talovaya, Dar'ya and Smelaya) and isolated valleys and hollows. In places, especially those close to the Manych river, the microrelief and mixed character of the plant and soil cover are quite pronounced. The terrace has a slight slope (0.002) which, on the northwest, is in the direction of the course of the Don river and on the north is in the direction of flow of the Manych river.

Depending on the relief, the water table is at depths of 2.5 to 4.5 meters; there is negligible drainage of the ground water. During the years of irrigation from 1951 to 1955 the water table rose and in August, 1955, was at a depth of 1.5 to 2.5 m. over most of the area; near the Azov canal it was at 0.5 to 1.0 m.; and in the western part of the area on the riverside ridge and the more elevated areas of slight or no irrigation it was at 3.0 to 4.5 m.

The accumulation of minerals in the ground water both before and after irrigation was quite variegated and was from 1.5 to 35.0 grams per liter. According to 1955 survey data, ground water with a mineral content of 5 to 15 grams per liter was most widespread. It was less common to find ground water containing 15 to 20 grams of salts per liter or more (up to 35 grams per liter). Near the Azov and some other irrigation canals the salt content was about 5 grams per liter. Salt accumulation in the ground water of the Manych foreland was fundamentally of the chloride type; in the southern part of the area adjoining the Azov canal it was of the sulfate type; in places sulfate-chloride and chloride-sulfate ground water was noted (using Alekin's classification, 1).

The soil-forming material consisted of alluvial deposits of the Manych river, covered by a layer of varying thickness (5 to 8 m.) of clay loam colluvium from the third terrace which obscured the boundary between the two terraces. The clay loam was underlain at depths of 1 to 10 m. by loamy sand and sand. Salt accumulation in the parent material varied, depending on the relief, the thickness of the colluvium and the degree to which each area was drained. In the southern part of the area, where there was greater drainage, there was principally sulfate and chloride-sulfate salt accumulation; in the northern part, adjoining the Manych river, it was principally sulfate-chloride and chloride.

Before irrigation, isolated parts of the area were subject to desalinization. The extent to which desalinization took place depended chiefly on the relief, the drainage of ground water and the general drainage of the locality. The fluctuating water relations of the area because of annual Manych river floods also affected the extent of desalinization and salinization. On some tracts with a more superficial water table alternating desalinization and salinization were noted, but in lower-lying places there was only salinization. The desalinized soils before irrigation are shown by the distribution of salts in them: the concentration increases with depth

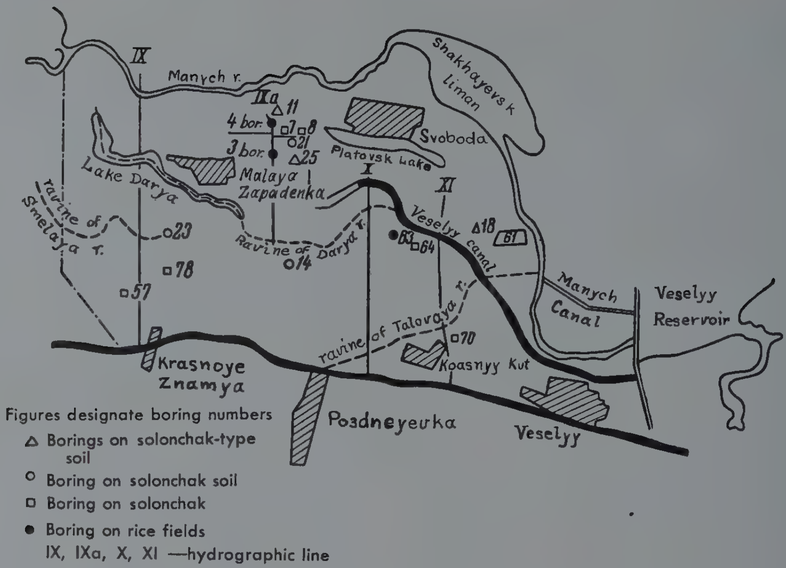

FIG. 1.—Outline of irrigated area.

on raised elements of the relief. In the desalinized soils one may note chloride-sulfate, sulfate and sometimes carbonate-sulfate salt accumulation in the soil profile. The sulfates usually predominate over the chlorides, the $Cl:SO_4$ ratio varying from 0.05 to 0.3 along the profile. With less degree of desalinization from the soil along the Manych foreland the accumulation of chlorides is observed at depths below 60 to 100 cm. ($Cl:SO_4 = 1.5$ to 3.0).

In the soils of depressed level areas and in depressions with a superficial level of saline ground water, there is an increased distribution of saline horizons and the accumulation of salts in the surface horizons, characteristic of the solonchak processes.

TABLE 1

Humus content in percent

Soil type	Depth in centimeters									
	0–5	5–10	10–20	20–40	40–60	60–80	80–100	100–130	130–160	160–200
Terrace chernozem	4.87	3.90	2.66	2.41	1.64	1.09	0.87	0.60	0.56	0.46
Meadow chernozem	4.37[a]			2.56	2.18	1.97	1.03	0.78	0.66	0.45

[a] 4.37 refers to the entire 0 to 20 cm. horizon.

In the northern part of the general area o level tracts varieties of meadow-solonchak soil are found with varying distribution of salt along the profile. In the southern part, and i elevated areas of the northern part, there are terraces with residual solonchak chernozems o the Caucasus Foreland type. Among these soil one encounters meadow-medium columnar chloride-sulfate solonetzes and, in depressions in the non-irrigated area, solonchak soils and solonchaks. The soils contain carbonates. In the superficial horizon (down to 40 to 60 cm.) the CaCO content is 0.2 to 0.6%; below this, from 130 t 160 cm., its concentration increases from 9 t 12%. Meadow-chernozem and terrace chernozem soils are similar with respect to humus content (see Table 1).

The soil texture is nonuniform and is characterized by the presence of coarse and fine layers and lenses containing up to 32% of fine sandy particles or 70 to 76% of clay particles. Such a texture causes quick seepage and lateral dissipation of irrigation and filtration water in the sandy layers and prolonged stagnation of them in clay layers. This creates different conditions for the water bearing strata.

The top 40 to 60 cm. layer of solonchak and the 100 to 130 cm. layer of slightly solonchak meadow chernozem soils have had their easily soluble salts leached: the total quantity of them in these layers is 0.07 to 0.5%. Beneath this and down to the water table (2.0 to 3.5 m.) it increases up to 0.3 to 0.6%; in the gypsum horizon at depths below 60 to 130 cm. it reaches 0.8 to 1.3%. In the soils of a belt along the Manych foreland there is a characteristically increased chloride content of about 0.05% in the presence of a small total salt content of 0.21% (in the 40 to 60 cm. horizon) and of 0.19% (in the 80 to 100 cm. horizon). The soils of this zone were formed on accumulated salt deposits of the Manych river when the chloride ground water was at a superficial level and the effects of this ground water may be detected at a depth of 40 to 100 cm. from the surface.

In the terrace chernozems the salt horizons are usually at a lower level. The content of salts down to a depth of 60 cm. varies from 0.02% to 0.07%; in the gypsum horizon at a depth below 80 to 160 cm. the salt content increases from 1.0 to 1.2% and near the water table it decreases to tenths of a percent. Chlorides have been leached of almost the entire thickness of the soil. Calcium sulfate and bicarbonate predominate in the upper part of the profile and sodium sulfate in the lower part. A somewhat increased degree of alkalinity (the occasional presence of CO_3^{--} at the 40 to 80 cm. depth) shows that some have solonetz tendencies. The accumulation of carbonate-sulfate salts in the upper layer of terrace chernozems and of chloride-sulfate salts in the lower shows that they are highly leached in comparison with meadow-chernozem soils. The effect of the ground water is traced down 80 to 100 cm. from the surface. The water table is 3.0 to 4.5 m. deep.

Before irrigation, the water of the Veselyy reservoir was distinguished by its high salinity. In 1950 its content of salts reached 3.7 to 4.1 grams per liter. Toward the beginning of irrigation, as a result of the introduction of water from the Kuban river into the reservoir to freshen it, the salt content decreased to 2.3 grams per liter in 1951 and to 1.3 grams per liter in 1952. In the 1953 irrigation season the salt content of the water was 1.3 grams per liter and in 1954 it was 1.2 to 1.3 grams per liter. In 1955, because of continued freshening of the reservoir by water from the Kuban river the salt content of the water decreased to 1.12 grams per liter. During the entire period of irrigation from 1951 to 1955 the irrigation water was not satisfactory, either with respect to the quantity of salts or to their qualitative composition (predominantly sodium chloride and sulfate); the degree to which the water had been freshened during this time, while considerable, was still not sufficient.

The salt content in the reservoir and canals during the 1955 irrigation period varied from 1.08 to 1.26 grams per liter; Cl^- was present in the amount of 0.20 to 0.23 gram per liter, SO_4^{--} 0.35 to 0.42 gram per liter; and a $Cl:SO_4$ ratio of 0.56 to 0.81 was characteristic of sulfate salinization. During isolated periods the content of chlorides increased or decreased and the water took on sulfate-chloride or chloride-sulfate salinization. There was a preponderance of sodium in the cation composition of the salts in the water. This accounted for 27 to 32% of the total number of milliequivalents of cations; the magnesium content varied from 7 to 13% and that of calcium from 8 to 11%. Of the total milliequivalents of anions, SO_4^{--} constituted from 22 to 28%, Cl^- from 15 to 18% and HCO_3^- from 6 to 9%.

Table 2 shows some data on the chemical composition of the water in 1950 and 1951, before irrigation, and during the 1952–1955 irrigation seasons. The chemical composition of the Veselyy reservoir, of the Veselyy canal for a 20 km. stretch and of the irrigation canals was identical. It can be seen from Table 2 that in 1955 every cubic meter of irrigation water contained about 1.12 kg. of salts.

The hydrological conditions in the area which changed as a result of irrigation and the considerable rise of the saline ground water during the years of irrigation exerted a noticeable influence on the soils of almost the entire area. The change rate of the soil processes was not the same everywhere and was due to different causes. The principal ones were: the amount of seepage from the canals, the rapidity and amount of the water table rise, the salt accumulation in and amount of drainage of the ground water, the irrigation regime and the crop-watering procedures, the arrangement of the crops, the relief, the evenness of distribution of the irrigation water on the surface, the soil tillage, and so forth. A considerable effect on the hydrogeological relations and the soil processes was exerted by the natural arrangement of the flooded rice plantings on small, unprepared plots in the absence of drainage for the ground water.

TABLE 2

Salt composition of the irrigation water of the Azovirrigation system

Place water sample taken	Date	Total ions	Cl^-	SO_4^{--}	Cl:SO$_4$	Cl^-	SO_4^{--}	HCO_3^-	$CO_3^=$	Ca^{++}	Mg^{++}	Na^+	Water index according to Aleki
			(gm./l.)			As % of total equivalents[a]							
Water intake at reservoir	May, 1950	4.16	0.9893	1.6002	0.62	17.21	27.84	4.72	0.23	7.20	10.17	32.63	S_{11}^{Na}
Same	June, 1951	2.33	0.5580	0.8005	0.94	21.49	22.72	5.14	0.65	7.39	12.66	29.95	SCl_{11}^{Na}
Same	6/15/52	1.33	0.2833	0.3996	0.95	19.72	20.53	8.96	0.79	9.70	8.34	31.96	SCl_{11}^{Na}
Same	6/4/53	1.30	0.2617	0.3885	0.91	18.82	20.63	10.12	0.43	10.50	6.43	33.07	SCl_{11}^{Na}
Same	6/15/54	1.24	0.2266	0.4020	0.90	19.32	21.51	8.50	0.67	10.51	6.50	32.99	SCl_{11}^{Na}
Same	6/26/55	1.13	0.2035	0.3924	0.70	16.63	23.67	9.24	0.46	10.49	11.82	27.69	S_{11}^{Na}
Reservoir, Veselyy and irrigation canals (average of 11 determinations)	May–June, 1955	1.12	0.2095	0.3920	0.73	17.04	23.60	7.89	1.47	10.16	10.85	28.99	S_{11}^{Na}
Rice basins (Average of 5 determinations)	May–June, 1955	1.19	0.2216	0.4065	0.74	17.40	23.35	8.73	0.52	10.54	10.73	28.73	S_{11}^{Na}

[a] The ionic composition is shown as percent of equivalents, as accepted by the Hydrochemical Institute, Academy of Sciences, USSR, and not as a percentage of the milliequivalents.

In the first year of irrigation from the Veselyy canal (1951) bog formation and salinization in spots were detected from a rise in the water table in the area adjoining the canal. In subsequent years these were intensified and in 1955 these processes were seen everywhere along the Veselyy canal and even at certain locations along the Azov canal. The salt content in the upper 2 to 5 cm. of the spots varied from 0.59 to 6.84%.

As a result of intensive seepage from the canals, of the leached and dissipated water laterally, of the hydrostatic pressure and of excessive watering, a noticeable rise in the water table began on the irrigated tracts. Salts accumulated on some of them both continuously and in spots. Then, when the water table rose over almost the entire irrigated area, the salinization became noticeable in many places. In the beginning stages the salt accumulations (especially of Cl^- and SO_4^{--}) developed in the middle of the soil profile and then in the surface horizons, too. The direction of the soil processes with irrigation of the area is shown by the salt profiles of the terrace chernozems in 1951, before irrigation, and in 1954, the fourth year after it had begun (Fig. 2). The level of the saline ground water which had been at a depth of 4 meters in 1951 rose to 2 meters during the years of irrigation. With this there was a considerable increase in the amount of salt in the 0 to 160 cm. soil layer and especially in the top 5 cm. where the salt content reached 0.77% as compared to 0.08% before irrigation. A residual solonchak-type soil was converted into a solonchak characterized by chloride salinization over almost the entire profile and by the accumulation of sodium, magnesium and calcium chlorides in the surface horizons.

There was clear salt accumulation throughout the soil in 1955. The slight degree of salinization is characterized by the analytical data of borings 11 and 20; the salt content of the soil of boring 11 varies from 0.08 to 0.41%, Cl^- from 0.01 to 0.11%, and the distribution of salts by depth shows a salt profile (Fig. 3a). At boring 20 the total content of salts in the top 0 to 20 cm. of soil is 0.05%, the Cl^- 0.01%; below this the total quantity of salts increases from 0.14% in the 40 to 60 cm. layer to 0.60% in the 160 to 200 cm. layer, while the Cl^- content increases to 0.04% and 0.20%. In the top 40 cm. of the profile, sulfates predominate; in the lower part, chlorides predominate. This points to some leaching of the upper layer and to capillary saturation of the lower layer (down to the water table at 2.0 meters); the salt content of the water is 19.9 grams per liter with chloride-type salinization (Cl:SO$_4$ = 1.9). The total content of salts and Cl^- in the soil at borings 11 and 20 had increased in comparison with their content before irrigation (borings 3 and 4).

Salt accumulation characterized by boring 26 is more pronounced. Here the total dissolved substances in the 0 to 20 cm. layer is also small—0.08%—but the Cl^- content has increased to 0.02%; below this and down to the water table the Cl^- content varies from 0.15 to 0.21%. The total salts increase with depth to 0.31 to 0.91% and, in the 60 to 200 cm. (gypsum) layer their concentration reaches 1.04%. The predominant ions among the salts are sodium and chlorine. The increased content of salts in the top one-meter layer and of Cl^- in the upper layer, as well as the chloride-type salinization at a depth of 20 to 80 cm., show the more significant salt accumulation in this soil as compared to that of boring 20. Ground water was encountered at 2.2 meters and its effect was detectable almost to the surface. There is a considerable degree of salinization of the ground water; total ion content was 19.39 grams per liter and the $Cl{:}SO_4$ ratio was 3.7.

The formation of the chlorides of calcium,

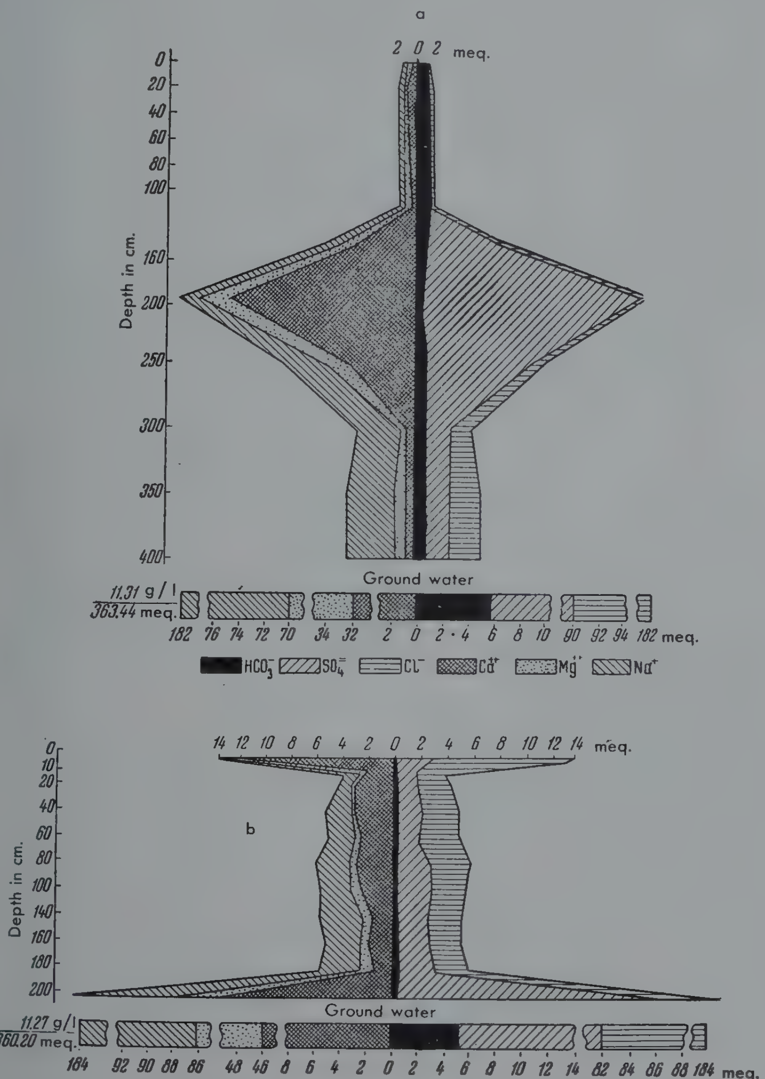

FIG. 2.—The salt profile of boring 3: a—May 10, 1951; b—September 16, 1954.

magnesium and sodium as a result of exchange reactions is characteristic of the initial processes of soil salinization (3, 5, 6, 7). In many locations in the area (see Fig. 1) salt accumulation took place owing to a rise in the water table because of seepage from the canals and the hydrostatic pressure of the seepage water, and also because of the high rates of irrigation and other factors. The most rapid and intensive salinization was noted on annually irrigated tracts without drainage near canals and on depressed areas of the relief, but also on areas adjoining flooded rice fields. In June, 1955, some tracts had spotty and continuous areas of solonchak. The soils formed here were characterized by a considerable content of salts in the most superficial layer. Thus, in the 0 to 5 cm. layer of boring 23 the total ions in the water extract amounted to 0.86%, but in boring 21 it reached 0.96%.

Of the salts of the topmost layer of boring 23, calcium chloride was predominant; below this the SO_4^{--} content increased and among the cations a preponderance of sodium began, the content of which varied with depth from 18 to 40% of the milliequivalents. The ionic composi-

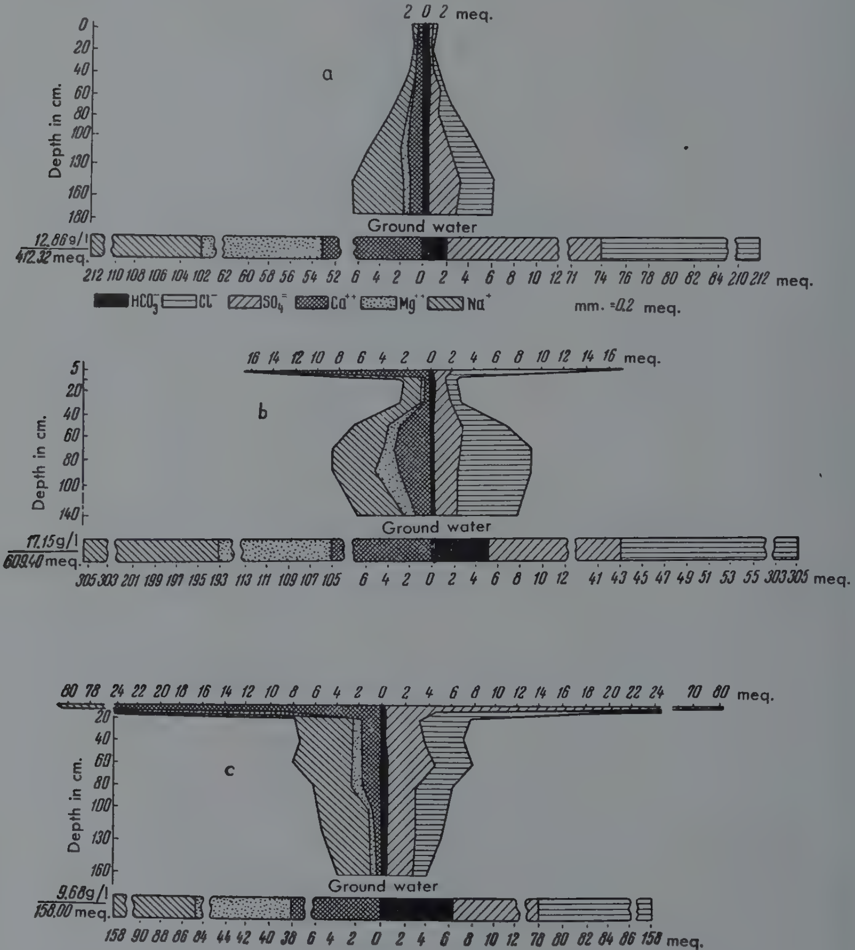

FIG. 3.—Salt profiles of borings in 1955: a—Boring 11, May 13; b—boring 21, June 23; c—boring 61, October 13.

tion of boring 21 is characterized by a preponderance of Cl^- along the entire profile, amounting to 19 to 44% of the equivalents, and of sodium (20 to 34% of the equivalents; see Fig. 3b).

The increased content of salts, their composition and distribution along the profile of these soils, the high water table and the salt composition of the ground water show the presence of secondary salinization of the surface layer with a superficial water table. In both borings the water table was at 1.4 meters; the mineral content of the water at boring 23 was 7.7 grams per liter and at boring 21 it was 17.2 grams per liter; types of salinization were sulfate and chloride, respectively.

An example of the sulfate-sodium type of salinization is provided by the soil of boring 14, in which the salt content of the 0 to 5 cm. layer was 0.90%, the Cl^- content was 0.12%, and SO_4^{--} content was 0.26%; salinization of the 20 to 60 cm. layer was of the chloride-sulfate-sodium type, while below, and down to the water table at 1.6 meters, it was of the sulfate-calcium type. The mineral content of the ground water was 7.5 grams per liter and the salinization was of the sulfate type.

A representative example of rapid and intensive salinization of soils is shown by the tract occupied by the State Selection Experiment Station (on the "Zavety Il'icha" collective farm), in the immediate vicinity of which undrained rice fields were located in 1954 and 1955. In 1953 dark spots of solonchak appeared at isolated spots in the area of the station. By June, 1955, a large part of the tract consisted of continuous solonchak with dead and dying crops. The Selection Station was forced to stop work on this tract and move elsewhere. The amount and distribution of salts on the salinized area is characterized by the salt profile of boring 61 (Fig. 3b). The total content of ions in the 0 to 5 cm. layer was 7.72%, while in the 5 to 10 cm. layer it was 1.15%. Salinization of these layers was of the chloride type with sodium, magnesium and calcium cations. In the layer from 10 cm. to the water table, in addition to chlorides, sulfates were found, chiefly sodium sulfate. The water table at boring 61 was at 1.6 meters, mineral content of the water was 9.7 grams per liter and salinization was of the sulfate-chloride type ($Cl:SO_4 = 1.0$).

Continuous solonchak areas appeared on other tracts next to rice fields. The salt profile of the secondary solonchaks showed an abrupt increase in the amount of salts with decreasing depth from the water table, which is typical for the solonchaks. The total salt content in the 0 to 5 cm. layer of solonchak (boring 64) was 3.87%, while that of boring 65 reached 6.09%. The Cl^- content in boring 64 varied from 2.35% (in the 0 to 5 cm. layer) to 0.09% (in that from 100 to 103) while the values for boring 65 varied from 4.12 (in the 0 to 5 cm. layer) to 0.15% (in the 60 to 80 cm. layer). The SO_4^{--} content in the corresponding layers of boring 64 varied from 0.37 to 0.22% and in boring 65 from 0.17 to 0.28%. The water table in boring 64 was found to be at 1.3 meters; mineral content was 10.7 grams per liter; and salinization was of the sulfate type.

Also characteristic is a salt composition of the soil in which calcium, magnesium and sodium chlorides are seen in the upper layer with mostly sodium chloride and sulfate in the lower.

Chloride salinization is sharply expressed in boring 65, in which the quantity of chlorine ions varies from 48% of the equivalents in the 0 to 5 cm. layer to 16% close to the water table. The water in the boring was found at a depth of 0.8 meter; its mineral content was 13.0 grams per liter; and the salinization was chloride type $Cl:SO_4 = 1.7$).

Salinized soils were also found on the southern part of the area on the Shvernik collective farm where, owing to irrigation, the water table had risen. This circumstance was one of the basic factors which favored the salinization both of this area and of one adjoining it. At first the solonchak spots developed on a depressed tract, then the entire area adjoining the depression was subjected to continuous salinization. As a result of this there was partial destruction of the rice crop in 1955. The content of Cl^- and SO_4^{--} at one of the solonchak spots was 0.12 and 0.75% in the upper horizon and 0.01 and 0.12% in the 30 to 40 cm. horizon, respectively.

According to the salt composition this was sodium-calcium sulfate solonchak.

Secondary salinization was also detected even on non-irrigated areas, that is, on the northwest corner of the same collective farm where water from the rice fields was discharged. Fluffy sulfate-sodium solonchaks with a continuous layer of salts on the surface also appeared here. Their chemical composition may be judged from the following data: Total ions 99.44%, Cl^- content, 10.76%, SO_4^{--} 66.63%, HCO_3^- 0.14%, Ca^{++} 0.07%, Mg^{++} 0.60%, Na^+ 31.24%; $Cl:SO_4$ ratio, 0.04.

Salinization also took place in the eastern part of the area near the rice tract of the Khrushchev Collective Farm. The amount of salts in the 0 to 5 cm. layer of the fluffy solonchak formed here reached 13.08%; Cl^- was 1.13%, SO_4^{--} 8.20%; in the 5 to 10 cm. layer total salts amounted to 5.29%, Cl^- to 0.44% and SO_4^{--} to 3.15%. A high salt content was found over the whole profile down almost to the water table (0.8 meters). Mineral content of the water was 14.95 grams per liter, there was sulfate salinization and the $Cl:SO_4$ ratio was 0.15. Rapid and continuous salinization of the soils was observed in most cases when the water table rose to 2 meters and higher. An increase in the soil salt content is reflected not only in the amount of salts accumulated in the upper horizons and the thickness of the salt horizons but also in the size of the areas being salinized.

The secondary salinization of the soils in the northern part of the area is accompanied by the accumulation predominantly of chlorides; in the southern part sulfates accumulate. This difference is evidently related to a change in the salt composition of the soils with irrigation, but chiefly with the nonuniform salinity of the parent material and of the ground water in these tracts, the boundary between which runs north of the Dar'ya ravine.

A different direction is taken by the processes on rice tracts, where the use of high rates of irrigation (50,000 to 60,000 m^3 per hectare) for flooding and maintaining the circulation of the water in the basins permitted the removal of easily soluble salts to greater depths.

Rice is sometimes grown for the purpose of leaching salinized soils. The effectiveness of this procedure depends to a considerable degree on the drainage conditions on the tract; with good drainage the soil will remain leached for a long time, but in the absence of drainage the salinity of the soils is quickly reestablished.

On the rice tracts of an irrigated area, the soluble salts from the upper horizons of the soil are leached downward. The thickness of the leached layer (130 to 160 cm.) depends on the depth of the water table, which in turn depends on underground drainage conditions. The amount of salts in such a layer (boring 63) varied from 0.12 to 0.23%, the Cl^- from 0.01 to 0.02%. Below, the salt content increases with the superficiality of the water table, preventing removal of salts by the gravitational flow of water or in connection with the presence of a gypsum horizon (boring 2). The considerable predominance of sulfates over chlorides ($Cl:SO_4 = 0.2$ to 0.6) observed over almost the entire soil profile and that of sulfates over carbonates in the middle part of the profile are characteristic for the "leaching processes" of the soils. The soil remained in this relatively eluviated condition for a considerable length of time in the fall after the discharge of the water and in the spring before the onset of high temperatures. The increase in total salts and in Cl^- and SO_4^{--} in the surface layer, observed on some rice tracts, is explained by the rise of the salt solution toward the surface. This process is similar to that observed earlier on rice tracts in the Golodnaya steppe and elsewhere (3). In the irrigated area it is observed especially near the State Selection Station which occupies the most favorable location (compared with others) with respect to the relief, viz. lying between the Manych River and the Talovaya ravine in an area of natural drainage. The tract is constructed along the lines of semi-engineered systems. On some crop rotation fields rice was grown for three years. Regardless of the favorable location and the existing drainage net, solonchak spots were observed in May, 1955, on some of the fields and along a part of the canals. Their appearance was linked to the poor functioning of the drainage net, which did not cause a fall in the water table, and to the capillary moistening of the soil surface horizons where the salts were deposited on water evaporation.

The removal of salts is, in some cases, accompanied by an increase in the alkalinity and a decrease in permeability; phenomena characteristic of soil solonization. Thus, in the analysis of boring 63 the 60 to 160 cm. layer showed an increased total alkalinity ($HCO_3 = 0.05$ to 0.07%) and sodium carbonate alkalinity of 0.003 to 0.005%), which was caused by the slow permeability (16 to 58 hours).

One can assume the possible occurrence of some solonization of the salinized soils when the salts are removed from them in the northern part of the area—a zone of predominantly chloride-type salinization. In the zone of sulfate

TABLE 3

Gypsum content in percent

Boring No.	Depth in centimeters								
	0–5	5–10	10–20	20–40	40–60	60–80	80–100	100–130	130–160
64	0.21	0.39	0.16	0.14	0.17	0.15	0.42	0.29	—
66	0.31	0.31	0.28	0.26	0.30	0.18	0.19	8.74	0.17

salinization the solonization processes would hardly be of significance or long duration. The solonization of soils should prevent carbonate accumulation and the deposit of gypsum in the salinization process. Table 3 gives some data on the gypsum content of soils which have become salinized.

Thus, the investigations showed that in the fifth year of irrigation secondary soil salinization was observed at different places in the area. Depending on the extent of salinization, three groups of salinized soils are noted: those with salt contents in the first one-meter layer of soil of 0.45%, 0.65%, and 1.4%. Calculations show that the first two soil groups may be improved by increasing irrigation rates amounting to 2,800 to 3,500 m^3 per hectare, while the third group of soils may be improved by leaching with 8,600 m^3 per hectare and drainage of the leached and ground water.

Conclusions

1. In the fifth year after the beginning of irrigation (1951–1955) of the investigated area, which is associated with the Azov irrigation system, the desalinization was replaced by salinization of the soils, and on isolated tracts the salinization assumed significant forms and extent. The basic cause of soil salinization is a rise in the water table to 1.5 to 2.5 meters as a result of seepage from canals and the excessive application of water. The spotty salinization which developed near canals in the first few years of irrigation then spread over the irrigated tracts and in some places became continuous. Grassland-chernozem solonetz-solonchak soils and residual solonchak terrace chernozems were converted into solonchak soils and solonchaks.

2. The fundamental measures for improving irrigated areas are: a) the correct use of water, with strict observance of the planned irrigation rates and of rational watering practices; b) control of seepage from canals; c) lowering the water table by drainage through a properly functioning drainage network; d) planting trees along canals; e) correct soil tillage; and others. These measures should be basic for any area.

3. For the effective drainage of seepage and ground water a drainage network should be completed and properly maintained by deepening and cleaning the canals, removing the cofferdams, assuring the discharge of water from the terminal portions of canals and also from Lake Platovsk in which a high water level causes reinforcement of ground water and a rise in the water table on adjoining areas. The drainage network should include not only the area associated with the Veselyy canal but also the area irrigated from the Azov canal.

5. For land improvement purposes, there must be a stop to the planting of flooded rice in the absence of drainage for the ground water. The correct cultivation of this crop on engineered systems affording drainage of the ground water will be an expedient measure for the improvement of those areas of the Veselyy and the eastern part of the Azov irrigation systems which have become and are becoming salinized.

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Methods

SURFACE RUNOFF ON SANDS

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Beginning with early papers by Vysotskiy there are numerous references in the literature to the absence of surface runoff on sands (10, 20, 13, 12, 19 and others). They actually refer to a fairly large area with duny dissected (undulating, hilly, ridged, mounded) terrain. No significant runoff actually takes place from such areas outside their boundaries if we exclude those systems of gullies which sometimes cut their way into the sandy terraces above floodplains.

However, if we consider the runoff from intermediate sandy terrain features—crests, slopes and valleys, we cannot believe in the complete absence of surface runoff. Considerable surface runoff of spring snowmelt is found along the still-frozen layer of sand and from summer cloudbursts along the saturated surface of the sand. This fact was noted by Vysotskiy (5, 6) in some of his later papers, and also by Polynov (17).

The runoff along slopes plays a fairly substantial part in smoothing dissected intermediate terrain features by water, not wind, without the important disturbance of the soil or plant cover generally typical of "normal" water erosion.

We have often observed spring surface runoff even on the sands of the southern semideserts (7) and summer runoff on the Narynsk sands of the lower Trans-Volga. The runoff is especially noticeable there because of the annual fall of dry needles, twigs, pine cones and the like in the irregular pine groves between the steep hills. The thin but more or less even deposit of fallen material (forest litter) covers the slopes of the sandy mounds, being washed down to the forested hollows. The evenness of this cover (litter), however, is disturbed by rain, especially by summer cloudbursts. The volume of water coming down in these cases considerably exceeds the capacity of the forest litter. Litter and sand are carried down by streams of water from the cloudbursts forming microterraces on the slopes and tiny alluvial fans at the foot of the mound. We have observed a similar but more pronounced phenomenon in the dry steppe zone, that is, in strips of sandy pine forest in the Irtysh foreland, Pavlodar region. The phenomenon developed especially distinctly in the summer of 1956, when moisture was abundant. Because of the scanty cover of steppe-type herbage (10 to 20%) and forest litter (0.5 to 2.5 cm.), the 20 to 30 mm. of precipitation caused noticeable runoff down the slopes.

We were not able to compare the rates of precipitation and runoff in detail. We present below only the few observations on erosion which we succeeded in making coincidentally with a study of the forest vegetation conditions in the sandy pine forests of the Irtysh foreland on the Tyumen forest tract of Kononersk Forestry Farm in Pavlodar region. The work was carried out jointly by the Forest Institute, Academy of Sciences, USSR and Moscow State University.

For the study of erosion we selected a type of tract with high, hilly dunes having an area of 1.20 hectares (80 × 150 meters), of which a topographic survey was made (Fig. 1). The elevation of the mounds (hillocks) was 3 to 10 meters. The crown density of the 90- to 100-year-old pine stands was 0.2 to 0.3. The soil had a light covering of forest litter, while in the clearings there were scanty stands of steppe herbage (Becker's fescue, Ivan's feathergrass or needlegrass, Koeleria) and mixed grasses. The sod-pine forest loose, sandy soil is made up of very fine grains of sand; the percentage of individual textural fractions in the 0 to 5 cm. layer at the crest of a dune is: 0.5 to 0.25 mm., 7.9%; 0.25 to 0.10, 56.1%; 0.10 to 0.05 mm., 32.4%; 0.05 to 0.01 mm., 0.6%; <0.01 mm., 3.0%; pretreatment loss, 0.3%. These sandy soils are of high permeability which at the crest, on the slope and at the bottom of the hilly dunes measured 6.52, 7.20 and 9.92 mm. per minute, respectively. Infiltration began almost simultaneously with absorption and the infiltration rate remained constant for the entire period of observation (1 hour). Regardless of the high permeability, water from snowmelt and cloudbursts on the slopes of sandy hills with slopes between 5° and 14° washes rills with small depressions owing to jets of water, forming at the outlet of the rill a deltoid area of water-laid deposits covering 20 to 200 square meters. The volume of eroded sand in a medium-sized area like this amounts to about 6 cubic meters for a catchment area of about 600 square meters. What was so interesting was not so much the depth of the washouts as the area of the erosion and deposition.

It is well-known (9) that washoff areas on steep clay and clay loam slopes are manifested by eroding the soil on the crest of the slope down to the B and sometimes down to the C horizon, with an increase in the size of the A horizon near the foot of the slopes. Similar processes take place in areas of loamy sand. In the Irtysh foreland on the weakly developed sod-pine forest sandy soils the situation is different. Here the sand transported by the water is almost eroded free of humus and the soil surface is covered by a layer of light-colored sand. At every blade of fescue and needlegrass the light sand forms a temporary miniature alluvial fan, is delayed longer and accumulates at the foot of the slope. The thickness of the alluvium here reaches 0.25 meters.

The extent of the sheet erosion of the sand was established by the method of one-meter squares (A, B, C, D and E), located on the slope from the crest to the foot of the hill (Fig. 1). On each one a determination was made of the density and composition by species of the grass, following which trenches were dug and sections were sketched. Fig. 2 shows how the rate of eroding increases successively on the areas A, B, and C with an increase in steepness of the slope from 5° to 14°. The profiles at D

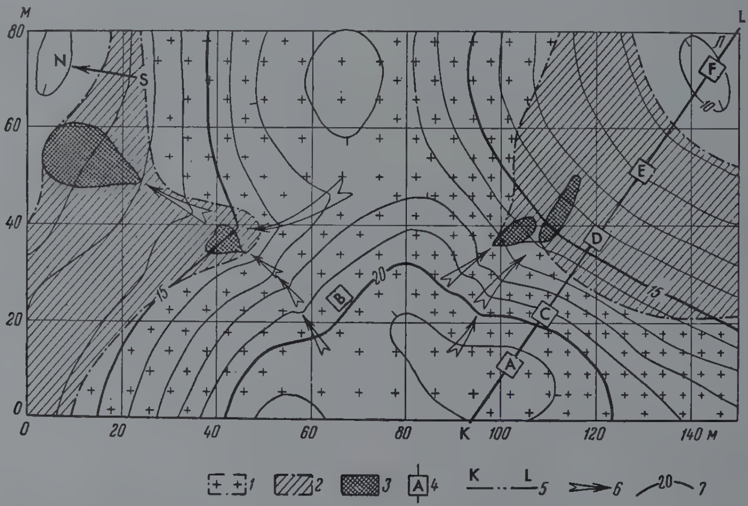

FIG. 1.—Topographic map of a sandy pine-forest tract on high, dune-like hills. 1—Eroded areas; 2—alluvial areas; 3—alluvial fan; 4—sample areas and ditches (A–E); 5—line of surveyed profile K–L; 6—main lines of surface runoff; 7—contour lines (interval, 1 meter).

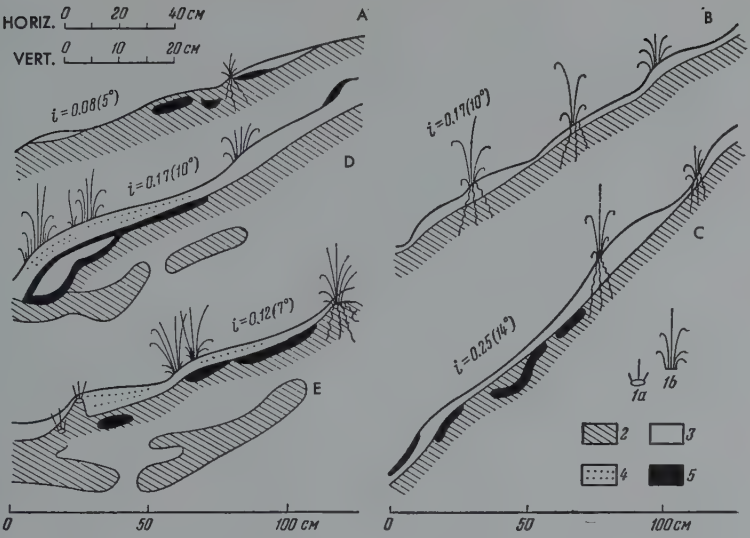

FIG. 2.—Trenches cut in sample areas A, B, C, D and E (see Fig. 1). 1a—Stand of dead grass; 1b—stand of living grass; 2—humus horizon of the sandy soil; 3—light sand without humus (eroded or alluvium); 4—same as 3, but in layers; 5—undecomposed forest litter (i = sin of slope angle).

and E on the concave slope of the mound show a considerable accumulation of sand with buried humus horizons and undecomposed forest litter. According to this, the zones of erosion and deposition are limited fairly definitely to the slope (Fig. 3). Each of the sample areas corresponds to a definite degree of erosion or deposition of sand (see Table 1). The boundaries of these stages are shown on Fig. 1.

However, observations on a small eroded tract do not enable us to judge the extent of the surface runoff on any large area. For this reason we followed the development of sheet erosion along a surveyed profile 3 km. long and, on the basis of the data obtained, calculated the percent of the area affected by erosion. It appeared that about one fourth of the area of the sandy pine forests on high and gently rolling hilly dunes had been subjected to fairly intensive erosion and about one eighth of the area had accumulated alluvium.

We did not succeed in breaking down the surface runoff into that caused by snowmelt and that caused by heavy rain, since that would have required a permanent observation site. However, the small amount of information already given is enough to state that surface erosion plays a considerable role in the process of soil formation on sands with dissection of the dune-like terrain; such erosion cannot fail to affect the evolution of the forms of eolian relief by causing a certain levelling. Our data on the existence of surface runoff on sands are in agreement with the statements of a number of authors in the most recent literature (1, 3, 11, 14, 15). Thus, according to Molchanov's data, the surface runoff on sandy soils may reach 80% of the amount of heavy rain falling, averaging 13, 20 and 30% on slopes of ⅛°, ½° and 8°, respectively, and 0 to 4% in forests.

The following causes may be mentioned for the appearance of surface runoff on sandy soils and sands having an infiltration coefficient large enough to absorb all the rainwater. The first—the presence of trapped air—has already been mentioned by Dryuchenko (8) and Vasil'ev (2). The second cause can be the hydrophobic nature of sand (3) or the wetting hysteresis (18). It arises both from the adsorption of air when the hygroscopic moisture is removed as a result of vigorous drying of the soil and from the formation of hydrophobic films on the surfaces of soil particles. The formation of the latter may take place at a fairly high rate under gently sloping pine forests, in which the fall of plant material is rich in resinous and silico-or-

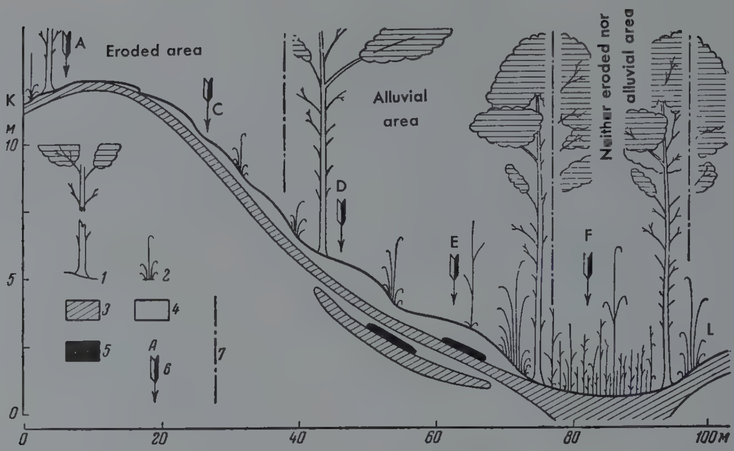

FIG. 3.—Outline of sheet erosion and deposition of sand. Profile of section through KL (see Fig. 1). Vertical scale highly exaggerated for the soil. 1—Pine trees; 2—grass stands; 3—humus horizon of sandy soil; 4—light humus-free eroded or alluvial sand; 5—buried undecomposed forest litter; 6—sites of sample areas A–E along the profile; 7—boundaries of eroded and alluvial areas.

ganic compounds (1). Probably the resultant cause of surface runoff from sands having a high coefficient of infiltration should be considered to be the special hydrodynamic conditions on the slopes of mounds by virtue of which the water, in moving down the slope, encounters less resistance than when it is absorbed vertically into the sand layer (16).

TABLE 1

Distribution of surface runoff (erosion and deposition) on dune sand according to measurements along a 3 km. profile

Terrain element	Slope, deg.	Percent of soil covered by grass		Average thickness of humus-free eroded or alluvial sand		Percent of area eroded or alluviated to any extent	Whether erosion or deposition predominant
		Actual	Projected	Cm.	Metric tons/ha.		
Upper part of slope	5	1	10	1	150	31	Erosion
Middle part of slope	10	1	10	4	600	16	"
	14	1	10	6	900	8	"
Foot of slope	7	2	21	20	3000	12	Deposition
Same terrain elements with less slope		1–2	10–20	none	none	33	Neither

Conclusions

Surface runoff of spring snowmelt and especially of heavy summer rains takes place on sandy, dissected terrain. It is observed in arid and moist regions both on sands without soil and plant cover and those with such cover, that is, in sandy pine forests.

Runoff down the slopes of sandy pine forests of the "high, hilly dune-like" type and accompanied by erosion and deposition of sand takes in up to two thirds of the area of the sandy pine forest. This process must affect the removal of humus and of clay and silt particles on the crests and slopes of the hilly dunes and the enrichment of the soils of the depressions between the dunes where the surface runoff comes to a gradual stop. On the whole, however, the phenomenon of erosion and deposition inhibits the soil-forming process. This is one of the causes of the weak differentiation of the loose sandy soils of pine forests into genetic horizons. Equally although slowly, erosion and deposition of sand by water must reflect the evolution of recent relief of sod-eolian sands.

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OPTICALLY ORIENTED CLAYS IN SOILS

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Optically oriented clays occur in different types of soils. They consist of aggregates of individual clay particles all possessing the same orientation. In polarized light such an aggregate behaves as one crystal, for which it is possible to determine the index of optical refraction, the birefringence, and other optical constants.

Optically oriented clays are easily detected in thin sections of soil samples with undisturbed structure under crossed Nicol prisms with simultaneous or periodic extinction. Optically unoriented clays are not visible when the Nicol prisms are crossed.

Optically oriented clays in soils were first discovered and described by Polynov (9) in thin sections of "ortstein-producing horizons of gray sandy soils." The method of soil study using thin sections came to be extensively used along with improvements of the methods applied to the preparation of the sections, after which optically oriented clays attracted the attention of many investigators: Frei and Cline (22), McCaleb (21), Brewer (19, 20), Altemüller (18), and others. Some research workers gave different names to these formations. In papers by Feofarova (17), Romashkevich (15), and Starykh (16), optically oriented clays are described as "secondary clays." Parfenova and Yarilova (7, 8) call them "mobile beidellite," "beidellite synthesized in the soil," and "iron beidellite." Foreign authors have used the designations "striated," "incrusted," "ribbon-shaped" and most often, "optically oriented clays."

The author (6) has detected optically oriented clays in the gray, cinnamon-brown carbonate-free soils of the Kirovabad massif and also when studying thin sections of the following soils: mountain-podzolic forest; mountain-forest brown; mountain-forest cinnamon-brown; shrub-dry steppe cinnamon-brown; sierozems and younger sierozem-meadow and meadow alluvial soils; and cultivated, watered soils on irrigation alluvium. It was shown that in soils in which the leaching is greatly hindered or completely lacking (such as cinnamon-brown soils and sierozems) there are no incrusted forms of "secondary clays." Instead there are forms of optically oriented clays which are quite specific in habitus. "Habitus" is used to designate the external form of accumulation of clays as distinguished from the "structure" associated with the crystal lattice of a mineral.

Accumulations of optically oriented clays in various soils differ not only quantitatively but also with respect to form, dimensions, and orientation with respect to other soil components. In the soils described below we have found the following types of oriented clays: 1) incrusted or "secondary" clays in the form of films on the walls of passages and cracks; 2) random-fiber clays in the form of fibers, extremely small scales and shells lying in different planes; 3) small accumulations as films on the surfaces of weathering primary minerals and rock fragments; and 4) accumulations of clay around inclusions of silt or sometimes of sandy particles or root fragments (in fresh deposits). The sizes of such accumulations may vary from microscopic to macroscopic layers consisting of poikilitic clays formed geologically. This is not a complete list of the abundant varieties of clays. Many other types are known, for example, those with a habitus of parallel or perpendicular fibers, and others.

Below are given descriptions of the microhabitus of clays and of some other specific characteristics important in clarifying the genesis of soils which developed both under moist climatic conditions in which the percolation of water was predominant and also under relatively dry climatic conditions in which leaching was greatly hindered.

Mountain-Forest Podzolic Soils (*Altay, profile 48, A. N. Rozanov*)

For all podzolized soils, including those of plains areas, the presence of optically oriented clays in the illuvial horizon in the form of incrustations along the cracks and pores ("secondary clays") is characteristic. Figure 1 shows a cross-section through one of these incrustations. By transmitted light the clay has a brownish-yellowish color. In some places it has a high concentration of iron and also of organic matter which, in transmitted light, have a dark-brownish and reddish color and include opaque limonitized areas. The incrustations are usually laminated. Sometimes the lamination is inconspicuous and the clay accumulations have a gelatinous habitus. Under crossed Nicols the extinction is periodic and the color reddish. Within the clays of this habitus there are usually extremely small darkly-stained particles of micron size.

It is important to note that the presence of "secondary clays" in illuvial horizons is always accompanied by eluvial horizons from which much clay has been removed. In the eluvial horizons mineral fragments usually do not have films visible under the microscope: as a result the podzolized eluvial horizon is light in color. In podzolic soils, in addition to clay in the form of incrustations, there are in the basic mass both of the illuvial and of the upper horizons very small quantities of optically oriented clays in the form of extremely fine aggregates, and also optically unoriented clays. (According to Kubiena [23] the basic mass is a very thin part of the soil consisting of humus and clay particles with an admixture of other extremely fine crystals. It is distinguished from the skeletal part of the soil which consists of fragments of primary minerals and rocks.)

The presence of round concretions with a concentric habitus is also characteristic of podzolic soils. These forms occur as particles of soil cemented together by brown iron oxides with manganese compounds. Iron accumulations always occur in soils in which there is the greatest accumulation of the incrusted forms of optically oriented clays, not only in podzolized soils but also in solodized.

There is no uniform opinion among investigators regarding the origin of the incrustations of optically oriented clays. Frei and Cline (22), who were the first to describe them in detail, accept as the most probable origin the eluviation of clays from the upper horizons as colloidal solutions under the protection of organic and other hydrophilic colloids (for example, SiO_2). Parfenova and Yarilova (8) consider that "the incrustational character of this mineral is evidence that it is synthesized from solutions percolating from higher levels of the soil." To this conclusion they have added the following consideration: "Mineral elements reach the soil surface in large quantities with the leaf litter. The easily mobile elements are leached from the litter and the more inert ones thus accumulate there: silica, iron and aluminum. Under the action of fulvic acids, which, in turn, are a product of the life processes of organisms, they are transferred along with the elements of the decomposing minerals into the depths of the profile, where their synthesis takes place" (7).

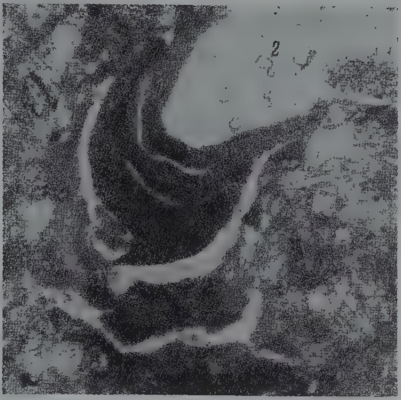

FIG. 1.—Incrustations of optically oriented clays along the walls of the pores of the illuvial horizon of a mountain-forest podzolic soil, profile 48, depth 85 to 95 cm. (magnification 5 × 20, Nicols parallel): 1—clay incrustations; 2—pores.

It is now generally known (1, 9, 10, 11) that the role of the higher and lower organisms in the soil clay formation is great, although the details of the process have not been fully clarified and we do not know the forms in which this occurs. Clay incrustations along cracks must not be considered only as a product of synthesis, and the incrustational nature of optically oriented clays cannot be considered as proof of their synthetic origin for the following reasons: 1. Optically oriented clays may be obtained from naturally-occurring optically unoriented clays by dispersing the particles and allowing them to settle undisturbed and dry out. Vikulova's method (2) for the optical determination of clays is based on this. 2. Incrustational, optically oriented clays are also detected in the illuvial horizons of solonetzes, solods and takyrs —that is, where there are suitable conditions for peptizing the clays and transporting them along the profile in colloidal solutions. Here, however, there is also peptization of the clay which has entered into the composition of the parent material. There is no basis for believing that clays are synthesized in takyrs where the

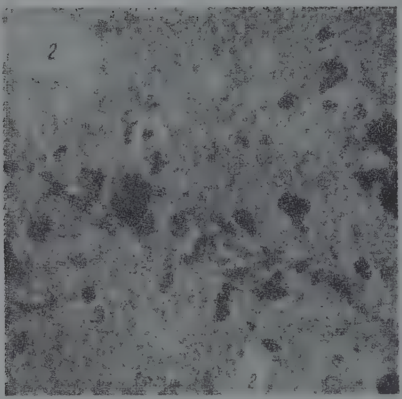

FIG. 2.—Optically oriented clay in brown mountain-forest soil of the Little Caucasus, profile 531, depth 65 to 83 cm. (magnification, 5 × 8, Nicols crossed): 1—pores; 2—residual minerals.

cycle of ash elements hardly exceeds a tenth of a kilogram per hectare. At the same time chernozems receive more than 1000 kg. per hectare per year of ash elements, but an accumulation of synthetic clay in the soil profile is not detected even though there is considerable growth of the soil. 3. Brewer (20) produced illuvial horizons with optically oriented clays artificially by putting suspensions of 60% illite and 40% kaolinite through columns of sand. Kubiena (23) in his experiments showed that clays from the illuvial horizon are easily transported further into the horizon by rainwater.

In consideration of all these facts, the author supports Frei and Cline's opinion that the presence of incrustational clays in the profile is an indication of illuvial processes in soils.

Brown Mountain-Forest Soils (Profile 531, E. M. Salayev)

From a study of brown mountain-forest soils of the Little Caucasus range which had developed on authigenous solid crystalline rock. It became clear that the occurrence of such optically oriented clays in almost all the horizons is characteristic of such soils, unlike the mountain-forest podzolic soils in which the optically oriented clays are concentrated mostly in the illuvial horizon. The habitus of most of the optically oriented clays of the brown mountain-forest soils is completely different. In addition to small accumulations of incrustational clays in the pores, they are distinguished by clays with a random-fiber habitus which make up the greater part of the soil. They are in the form of thin strips, fibers, granules and scales oriented in different directions, which gives the mass a net-like or random-fiber habitus which can be detected with crossed Nicols (Fig. 2).

The ratio of these two types of optically oriented clays changes, depending on the extent to which the soil has been leached: the more the soil has been leached, the more there are of the incrustational forms of clays in the pores. This is found not only in the soils of the Little Caucasus but elsewhere in the world—for example, in the soils of China. Thus, the small accumulations of incrustations of optically oriented clays in the pores of the brown mountain-forest soil being described is evidence of the slighter development of the leaching process than in mountain-forest podzolic soils. Further evidence for this is found in certain other pecularities of the microhabitus of brown soils. For example, they have smaller accumulations of iron concretions although the soil is generally fairly rich in iron hydroxides which are deposited in the weathering minerals in the form of extremely fine granules of limonite, most often in the upper horizons. Evidently conditions are not suitable for the migration of iron from some places or its concentration in others. Further evidence of less leaching is given by the accumulations of fine needles of calcite in the lower part of the profile (at a depth of 90 cm.).

In general the brown soils of the Little Caucasus are characterized by a high clay content, the occurrence of small accumulations of clay incrustations in the middle and lower parts of the profile and a random-fiber habitus of most of the optically oriented clays.

Cinnamon-Brown Mountain Forest Soils (Profile 654, E. M. Salayev) and Cinnamon-Brown Shrub-Dry Steppe Soils (Profile 622, Described Jointly by the Author and A. N. Rozanov)

The cinnamon-brown soils investigated had developed on marly limestone (profile 654) and on porphyrites (profile 622). They are distinguished from mountain-forest brown and podzolic soils by the absence of illuvial clays in the form of incrustations on the pores and cracks (Fig. 3). They are characterized by an even higher clay content of the soil profile and by a negligible content of residual minerals and rock fragments. Most of the optically oriented clays have a random-fiber habitus. The scales and fibers of optically oriented clays are only microns thick. For cinnamon-brown soils, just as for the brown soils, the occurrence of a large number of branching pores with rounded edges is characteristic.

In the upper horizon most of the soil consists of aggregated humus-clay formations in which there are areas of optically oriented and unoriented clays mixed with humic matter and with undecomposed and half-decomposed plant residues. It is interesting to note that deposits of carbonate often occur in cinnamon-brown soils. They are sometimes present in the topmost horizon. When this occurs the clay usually has no optical orientation in places where the carbonates have accumulated. The absence of incrustational forms of optically active clays and the occurrence of carbonates in the profile is evidence that intensive leaching is not taking place. For the same reasons the iron hydroxides formed by weathering and soil formation remain in place. This was especially clear in the thin sections of profile 622, since the parent material—porphyrite—contained pyrite. In places where the pyrite had been oxidized, limonite remained and gypsum had crystallized out in the lower part of the soil profile.

Thus, surveying a series of soil from the mountain-forest podzolic soils through the brown soils to the cinnamon-brown mountain-forest and shrub-dry steppe soils, we can notice a gradual increase in the extent of clay formation and a decrease in the thickness of the incrustations of optically oriented clays down to the point of thin films and, in the cinnamon-brown soils, to the point of their complete disappearance. While there may be a considerable number of iron concretions in the podzolic soils, there are fewer in the brown leached soils, very few in the cinnamon-brown soils transitional to the brown soils, and none at all in the cinnamon-brown shrub-dry steppe soils. The carbonate content of the soils increases in the same direction. In the brown soils the carbonates are represented by accumulations of fine needles in the deepest horizons, in contact with the parent material. In cinnamon-brown soils they lie at a higher level in the form of accumulations of fine needles and microgranular aggregates, while in the cinnamon-brown shrub-dry steppe soils the microgranular carbonate accumulations are detected at the surface in some places. All of this information confirms the fact, already known from soil-geographical observations, that there is a decrease in the intensity of the illuvial processes in the series extending from the mountain-forest podzolic soils to the cinnamon-brown soils.

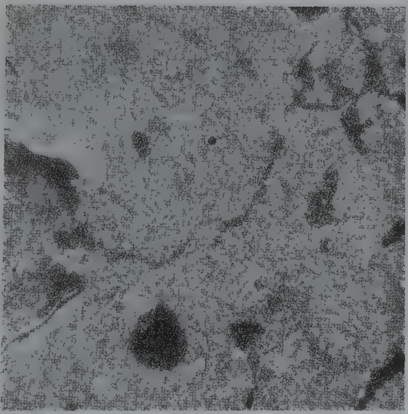

FIG. 3.—Random-fiber habitus of a high-clay horizon of cinnamon-brown mountain-forest soil of the Little Caucasus, profile 654 (magnification 8 × 20, Nicols crossed).

In the sierozem soils on loess, where leaching is even more hindered and there are no conditions favoring dispersion of the soil mass, there are no incrustational forms of optically oriented clays. Clay formation is slight and optically oriented clays are detected in such soils in negligible quantities in the form of isolated films on the surfaces of primary minerals undergoing weathering. Most of the clays have no optical orientation and are assembled in microaggregates.

In sierozems on loess and in cinnamon-brown soils formed on authigenic rock, where the illuvial processes are hindered by specific hydrothermal conditions, there is no other way of forming optically oriented clays except by intrasoil weathering and clay formation in primary rock-forming minerals *in situ* under the influence of the soil-forming processes. The origin of the random-fiber habitus of optically oriented clays can be fully explained on this basis if it is considered that clay formation begins and continues along the finest cracks and pores which penetrate the rock in various directions. They proceed more easily along the surfaces of the soil-forming minerals which are more accessible to microorganisms, to the soil solution and to the action of the air. The random-fiber habitus of optically oriented clays and the occurrence of mutually isolated films on the surfaces of weathering minerals can be considered as signs of their formation *in situ*.

Conclusions regarding the possibility of formation of clays *in situ* by intrasoil weathering are not new. Intrasoil clay formation processes, which develop in occult form in sierozem formation, in more conspicuous form in the formation of gray cinnamon-brown soils (13, 14) and to a very emphatic extent in the formation of cinnamon-brown soils (3) were long ago described and proved by other methods. The micromorphological development of this process has been established by the use of the microscope.

In all the cases noted above the formation of optically oriented clays has been related to soil formation. Such clays may arise during the formation of parent material by sedimentation from water carrying alluvium or deluvium if the clays are peptized. Under natural conditions the clay particles are more often found in coagulated condition (that is, they are transferred by the water in the form of microaggregates), so that the alluvial and deluvial deposits consist more often of unoriented clays. Conditions favoring peptization also make possible the formation of optically oriented clays when the suspensions dry out. Such clays usually include particles of silt and fragments of plants which are also transported by water. Sometimes they form microfilms and microlamellae which are fairly pure. We were able to observe such formations in the sierozem-meadow soil of the Zeravshan valley. As seen from Figure 4 these formations have a completely different habitus and are distinct from all the forms listed previously.

Especially favorable conditions for optically oriented clays occur in the development of takyrs. The water stagnating on them has an alkaline reaction, which favors the peptization of the clays and crust formation (5). Thus it is no coincidence that in takyrs one may observe the two forms of optically oriented clays described by Feofarova (17)—"secondary clays" and "mixed clays." It may be assumed that the latter type was formed during sedimentation, so that it includes particles of silt and sometimes of sand. They are all subsequently buried by alluvial deposits.

Thus, optically oriented clays have different forms of habitus related to the different conditions under which they were formed. Brewer (20) proved the possibility of forming optically oriented clays not only by illuviation, but *in situ* as a result of the weathering of rock and also sedimentation from the water transporting alluvium. However, Brewer's article does not distinguish the specific characteristics of the habitus for optically oriented clays of various origins.

The mineralogical nature of the optically oriented clays of the soil has not yet been fully clarified. Thermal and x-ray analyses of soils containing an abundance of optically oriented clays show a preponderance of beidellite. Parfenova and Yarilova (7, 8) found this to be iron beidellite, while Brewer (20), Stremme (24) and others noted that the incrustations of optically oriented clays could be formed of illite, iron illite, or a mixture of kaolinite with illite. Popov (12) observed optically oriented clays in samples consisting of montmorillonite. He noted that kaolinite does not provide such formations. His investigations show that the character of the clay habitus is strongly affected by the adsorbed cations—specifically, that clays saturated with calcium form anisotropic aggregates of rectangular isometric shape. In water they neither expand nor lose their anisotropy. Sodium saturated clays form odd-shaped aggregates which are anisotropic when dry but which swell, disintegrate and lose their anisotropy when wet.

We may consider that optically oriented clays can be formed by montmorillonite, beidellite, illite, minerals of the polygorskite group and by other highly disperse minerals. It is generally known that aggregates of oriented particles can easily be formed from individual particles of clays. The orientation is caused by the flaky shape of these particles: on sedimentation they tend to occupy the most stable position possible so that they all lodge in one plane. When they dry out the aggregates of these oriented particles become hard. If we adhere to Rebinder's terminology we can call such a structure "crystallizational-condensational."

On the basis of his own investigations, Popov (12) concluded that clay particles may become oriented under the influence of surface tension. Other investigators have noted this factor. The surface tension of water may prove to be one of the important causes in the formation of the incrustational forms of optically oriented clays.

"Secondary clays" may evidently be formed not only from descending flow of colloidal solutions but also from rising and lateral capillary flow. Brewer considers the alternate wetting and drying to be the principal cause of the orientation of clay particles formed *in situ* by the weathering of rock. Here, too, the influence of surface tension is also evident.

Optically oriented clays are also formed under the influence of mechanical pressure. This phenomenon is known to petrographers from sedimentary rocks, and Popov (12) carried out appropriate experiments on it. Under the natural conditions of soil formation this process is evidently not important. The orientation of clay particles in soils takes place in general under the influence of surface tension and with periodic alternate wetting and drying. Mechanical pressure may be important as a factor in the formation of optically oriented clays when the soils are tilled, because of the effect of the tillage implements.

These differences in the microhabitus of soils are manifested also in their hydrophysical properties. It is not difficult to see that horizons with maximal accumulations of incrustational optically oriented clays (the illuvial horizons of podzolic soils, solonetzes, solods and also of takyrs) have hydrophysical properties which are extremely unfavorable for plants. They are very slightly permeable, of extremely hard consistence when dry and are difficult to till mechanically. Soils in which optically oriented clays are observed in minimal quantities, such as chernozems, sierozems and others, are distinguished by more favorable properties. The formation of very slightly permeable crusts during irrigation is obviously related to the formation within them of optically oriented clays as a result of intense dispersion of the tilled soils, alternating moistening and vigorous drying of the surface and the sedimentation of clays in the soils. We are far from knowing all the causes and conditions favoring the formation of different forms of optically oriented clays in soils. A study of them is of definite practical and theoretical interest.

Conclusions

1. Optically oriented clays are noted in many soil types. The habitus of their aggregates (form, size, mutual orientation, and other specific characteristics) varies and is determined by the conditions under which they were formed.

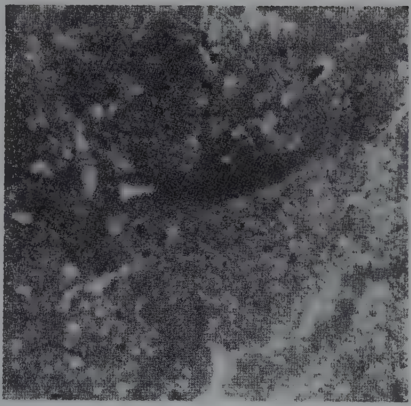

FIG. 4.—Optically oriented clay formed during sedimentation, profile 62, depth 0 to 50 cm. (magnification 5 × 8).

2. Optically oriented clays are formed by different processes: the migration of clay suspensions along the soil profile and the concentration of clays in the illuvial horizon in the form of crusts or incrustations on the walls of cracks and pores; they are formed *in situ* by weathering and soil formation; as a result of sedimentation from and the drying of suspensions carrying deluvium.

3. Aggregates of optically oriented clays may be formed by various highly disperse minerals. Their orientation is favored by the flaky habitus of the individual particles, their ability to cohere to each other when dry, the surface tension of water, mechanical pressure and other factors.

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THE QUALITY OF WATER-STABLE AGGREGATES AND THEIR COMPOSITION BY GROUPS AS DETERMINED BY A. F. TYULIN'S METHOD

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Soil structure is usually characterized only by the number of water-stable aggregates without consideration of their quality. It is well known that Tyulin (7) developed the concept of unequal qualitative values of soil aggregates in linking the properties of aggregates with their genesis. According to this concept, in the rhizosphere, where there is a high content of organic matter and intensified development of microbiological activity, the soil minerals undergo biological weathering and the poorly soluble oxides thereby formed—those of iron, aluminum, silicon and manganese—are deposited on the surface of the soil particles and become firmly attached. Under these conditions microaggregates are formed which are comparatively resistant to the destructive action of water (group II microaggregates, in Tyulin's terminology).

In parts of the soil with little or no easily decomposable organic matter, the decomposition of the soil minerals takes place more slowly. The surface of the soil particles is covered predominantly by less stable compounds in which there is participation by humified organic matter which has migrated from the rhizosphere. This type of soil particle was designated as group I by Tyulin (7). Microaggregates formed by particles of this group and which are completely saturated by calcium and magnesium cations are also water-stable, but they are qualitatively extremely different from the group II microaggregates. When divalent cations are replaced by monovalent (potasium, sodium, ammonium), the group I microaggregates are easily peptized, while those of group II undergo peptizing with much more difficulty.

There is always a mixture of group I and II aggregates in different ratios. In this connection the quality of soil structures may differ sharply in spite of the fact that they may have the same total number of water-stable aggregates. Thus, for a general evaluation of the quality of soil structure, importance should be attached to the composition by groups of the microaggregates which compose the water-stable aggregates.

The chemical composition of the microaggregates of groups I and II have been studied in adequate detail for many soils (6, 7). However, the connection between the composition by groups and the soil structure is still not clear. We have carried out research to clarify the interrelationship between the composition by groups of the primary soil microaggregates, the stability of the aggregates and the coherence of the soil.

The subjects of investigation were carbonate-free chernozems and some podzolic soils (plow layer). As Table 1 shows, the chernozems consisted predominantly of clay loams and silt loams and were characterized by coarse silt content (25 to 40%), while the sod-podzolic soils were mostly silt loams containing 45 to 60% coarse silt.

The relative content of group I and II microaggregates (by Tyulin's method) in these soils varied within wide limits (Table 2).

A comparison of the ratio of the microaggregates of group I to group II (in Table 2) with the amount of clay in the particle size analysis (Table 1) shows that as the ratio of the groups decreases, both in chernozems and in podzolic soils, a decrease is observed in the amount of clay in the particle size analysis, regardless of the increase in the percentage of humus. This can be explained by the fact that in soils with a higher content of group II microaggregates the fine clay particles (<0.001 mm. diameter) are firmly bound to the surfaces of the silt separates and are not set free during the chemical pretreatment for particle size analysis.

All the soils studied, as mentioned before, were characterized by a high content (25 to 50%) of coarse silt (0.01 to 0.05 mm. diameter). Some authors (Vershinin, 2; Godlin, 3; Vadyunina, 1) consider that coarse silt does not form

TABLE 1

Particle size analysis by N. A. Kachinskii's method (4)

Description of soil	Diameter of soil separates (mm.) as % of soil weight						
	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001
Thick fine-texture clay loam chernozem (Voronezh region)	4.44	0.77	6.37	31.46	11.34	16.64	28.84
Leached silty clay loam chernozem (Sumsk Experiment Station)	0.31	12.25	10.08	42.80	5.80	8.96	23.05
Slightly leached fine-texture clay loam chernozem (Kurgansk region)	5.08	15.49	11.49	25.39	8.08	15.82	24.65
Strongly degraded chernozem (Moscow region)	0.6	2.76	6.84	40.64	17.52	11.50	20.66
Dark-gray forest-steppe soil (Sverdlovsk region)	0.92	—	4.72	42.63	19.34	14.96	17.43
Thick fine-texture clay loam chernozem (Kursk region)	1.45	2.35	10.86	46.20	11.90	12.49	14.75
Sod medium-podzolic soil (Dolgoprudnaya Experiment Station)	1.76	6.68	11.81	48.99	8.95	11.42	10.07
Sod medium-podzolic soil (Barybino Experiment Station)	1.06	1.34	10.64	50.77	15.66	7.93	7.40
Sod medium-podzolic soil (Teaching farm, Timiryazev Agricultural Academy, Otradnoye)	4.17	5.49	14.87	44.79	14.92	7.32	4.1

aggregates, but Savvinov (5) and Tyulin (6), on the contrary, refer to the direct participation of coarse silt in the composition of structural aggregates. Our investigation of the particle sizes of the water-stable aggregates larger than 1 mm. showed that coarse silt predominates in their composition. A study of the tendency of coarse silt to form aggregates was made by causing the particles of group I and group II as a whole to cohere to separate particles of coarse silt, that is, together with the clay and silt fraction, or with 0.001 to 0.01 mm. diameter particles, or with the clay fraction (particles <0.001 mm. diameter). The ratio of the viscous particles to the coarse silt particles in all these experiments was uniformly 1:1. Under these conditions the particles of group I and II as a whole plus clay aggregated more than 80% of the coarse silt, while the 0.001 to 0.01 mm. diameter particles, without clay, aggregated a total of 10 to 15% of the coarse silt.

We conclude from this information that when aggregation takes place by means of particles smaller than 0.01 mm. diameter, the interstices between the particles of the coarse silt being formed into aggregates are filled not only by clay, but also by fine (0.001 to 0.005 mm. diameter) and medium (0.005 to 0.01 mm. diameter) silt.

By this means it was established that not only coarse silt, but also fine sand is aggregated in appreciable quantities. In these experiments no material difference was observed between the aggregating properties of particles of group I and of group II. However, under natural conditions a clear difference is observed between the content of aggregated coarse silt and that of water-stable aggregates in soils with a different ratio of the groups. In all our studies of soils distinguished by closely similar content of coarse silt particles, when there was an increase in the content of group II microaggregates there was also an increase in the formation of aggregates of coarse silt. At the same time there was an increase in the content of water-stable aggregates larger than 0.25 mm. diameter. For example, in the chernozem from the Sumsk Experiment Station, distinguished by the widest ratio of the groups (I:II = 7), the total quantity of water-stable aggregates larger than 0.25 mm. diameter was 16%, while the content of coarse silt not forming aggregates was 52.3%. On the other hand, in the chernozem from Kursk region, which had the narrowest ratio of the groups (I:II = 0.24), 84.6% of the coarse silt was formed into aggregates and only 15% remained free, while the total amount of water-stable aggregates was 66.0%.

An even more explicit picture of aggregate formation by coarse silt was observed in soils from plots of a prolonged experiment by the Experiment Station of the K. A. Timiryazev

Moscow Agricultural Academy. These soils are fairly sharply differentiated in the ratio of the groups (Table 3).

Thus, on the plots of non-fertilized continuous fallow almost all of the coarse silt was in the non-aggregated state. Fertilizing the soil annually at the rate of 25 metric tons of manure per hectare caused only a negligible increase in the aggregation of coarse silt—5.4% altogether—while under grasses aggregation increased up to 45%.

We conclude from the results of our experiments that coarse silt is capable of forming water-stable aggregates and that its tendency to aggregation increases in proportion to an increase of group II particles, characterized by a higher content of sesquioxides.

Let us consider the quality of water-stable aggregates in soils with different ratios of the groups. Tyulin's concept of the soil content of the two qualitatively different groups of microaggrates, suggests delineation of two paths for the aggregation of silt particles and the formation of water-stable aggregates: a) As a result of the coagulation of the free clay fraction of group I by bivalent cations of calcium and magnesium (the aggregates formed in this way are easily peptized by monovalent cations by the Gedroits method); and b) aggregation by mutual coherence of the group II particles (this type is not peptized by the Gedroits method).

To determine the type of water-stable aggregates or their quality with respect to resistance to the peptizing action of sodium ions, we proceeded as follows: Ten grams of soil were taken, put through a sieve with a 3 mm. opening and, in the first part of the experiment, were separated into the following fractions by differential sedimentation without any previous treatment: >0.25 mm.; 0.1 to 0.25 mm.; 0.05 to 0.1 mm.; 0.01 to 0.05 mm.; 0.005 to 0.01; 0.001 to 0.005 mm.; and <0.001 mm. In the second part a similar soil sample was saturated with sodium ions and, freed from excess salt by dialysis, was subjected to the same fractionation. In this treatment the fractions obtained were more dispersed since the sodium ions peptized the gels arising through the coagulation of the clay by bivalent cations.

TABLE 2

Group ratio in chernozems and podzolic soils

Description of soil	Humus content, %	Group composition		
		I	II	I:II
Chernozems				
Thick fine-texture clay loam chernozem (Voronezh region)	5.77	54.5	6.7	9
Leached silty clay loam chernozem (Sumsk Expt. Sta.)	5.02	37.0	5.0	7
Slightly leached fine-texture clay loam chernozem (Kurgansk region)	9.2	46.05	9.96	4.6
Strongly degraded chernozem (Moscow region)	8.15	37.9	18.07	2.0
Dark-gray forest-steppe soil (Sverdlovsk region)	10.6	21.0	50.05	0.41
Thick fine-texture clay loam virgin chernozem (Kursk region)	9.01	10.8	41.5	0.24
Sod-podzolic Soils				
Sod medium-podzolic soil (Dolgoprudnaya Experiment Station)	1.52	24.4	10.5	2.3
Sod medium-podzolic soil (Barybino Experiment Station)	1.61	24.0	13.9	1.7
Sod medium-podzolic soil (Otradnoye Teaching Farm)	1.84	12.77	20.04	0.6
Sod medium-podzolic soil (Experimental tract of the Timiryazev Agricultural Academy—continuous unfertilized fallow)	0.90	16.7	4.5	4
Same, fallow fertilized with 20 metric tons of manure	1.48	15.8	5.25	3
Same, continuous grass crop	1.76	9.8	10.3	0.9

Assuming that sodium cannot peptize aggregates arising through mutual coherence of group II particles, the third treatment included (in addition to saturation by sodium ions) subjecting a similar sample to mechanical dispersion followed by the same fractionation. The results of the fractionation following the action of water, sodium ions and sodium and mechanical dispersion show (Table 4) that in a soil with a wide ratio of the groups (I:II = 37:5) the macro- and microaggregates are easily peptized. Because of the action of the sodium ions al-

TABLE 3

Amount of aggregated coarse silt in soil from the plots of a continuous experiment

Experimental treatment	Content of particles of "fine particles" as % of weight of soil			Total content of coarse silt in soil, %	As % of total	
	Groups				Aggregated coarse silt	Non-aggregated coarse silt
	I	II	I:II			
Continuous non-fertilized fallow	16.4	4.5	4	25.5	0.3	99.7
Continuous fallow manured at 20 metric tons per hectare	15.8	5.25	3	28.1	5.7	94.3
Continuous grass	9.8	10.3	0.9	20.36	45.0	55.6

TABLE 4

Fractionation of soils after different methods of peptization

Type of peptization	% of particles separating from aggregates (diameter in mm.)						
	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001
Leached silty clay loam chernozem from Sumsk Expt. Sta. (I:II = 37:5)							
Peptization in water	12.93	21.0	25.7	34.8	3.96	0.76	0
Sodium saturation	0.4	2.6	13.9	46.9	9.45	6.9	20.4
Sodium saturation + trituration	0.2	1.0	12.0	40.9	13.4	4.15	23.3
Dark-gray forest-steppe soil from Sverdlovsk region (I:II = 21.0:50.5)							
Peptization in water	38.0	14.0	18.5	24.0	2.5	0.7	0
Sodium saturation	4.95	7.6	17.0	49.0	3.6	9.5	9.3
Sodium saturation + trituration	0.4	0.6	4.0	22.68	23.8	16.2	31.0

most all of these aggregates are broken down into their component particle sizes, dispersing 20.4% clay. Additional mechanical dispersion increased the yield of clay by only 3%.

In soils with a narrow ratio of the groups, the action of sodium ions left 4.95% of the aggregates larger than 0.25 mm. diameter intact, but most of those which did break down dispersed not into their ultimate particle size but into microaggregates which were resistant to the action of sodium ions and which continued to retain a large amount of the clay. Very little of it—a total of 9.3%—separated out into the dispersed state. Only after the application of mechanical dispersion, which is known to assure a complete breakdown of all soil aggregates into their ultimate particle size, was there separation of the whole amount of the clay (31%).

Such peptization and fractionation of the soils showed that aggregates of different diameters have a far-from-uniform resistance to the peptizing action of sodium ions. This led us to study the resistance of each fraction of the aggregates separately. To this end aggregates of diameters larger than 2 mm., 2 to 1 mm., 1 to 0.5 mm., 0.5 to 0.1 mm., and 0.1 to 0.05 mm. were isolated. The fractions greater than 2 mm. diameter and from 2 to 1 mm. diameter were saturated with sodium ions in one treatment or were treated with 0.05N HCl and boiled with alkali in another, as in the chemical pretreatment of soil for particle size analysis. It was assumed that such chemical pretreatment can replace mechanical dispersion, but later it proved not to assure complete breakdown of the microaggregates. For this reason a third, stronger, type of peptization was introduced for the 1 to 0.5 and 0.05 to 0.01 mm. diameter aggregates: chemical pretreatment of the soil for particle size analysis plus mechanical dispersion.

The results of the analyses given in Table 5 show that in soils with a small content of group II particles, sodium easily peptizes all the macroaggregates and a large part of the microaggregates. However, in soils with a high content of group II microaggregates, not only the microaggregates but also the macroaggregates from 1 to 0.5 mm. diameter show good resistance to dispersing action of sodium ions and to the chemical pretreatment of the soil for particle size analysis. Only after mechanical dispersal methods have been applied do these aggregates disperse fully, separating 36.32% clay: consequently they are the most stable aggregates.

The differential resistance to peptization by sodium ions of aggregates 1 to 0.5 mm. in diameter is revealed with special clarity by comparing their physical condition with complete saturation by sodium ions on funnels (calcium test). Aggregates isolated from chernozem from Sumsk Experiment Station (I:II = 37:5) and brought to air-dried consistency at room temperature were converted into a single dense mass penetrated by deep cracks, while aggregates isolated from dark-gray forest-steppe soil (I:II = 21.0:50.5) were completely unchanged and ran out of the funnel like coarse sand. From this, the conclusion may be drawn that these aggre-

TABLE 5

Fractionation of aggregates after different types of peptization

Type of peptization	Diameter of aggregates being peptized	% of particles of peptized aggregates (diameter in mm.)							
		>0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001
Leached silty clay loam chernozem from Sumsk Expt. Sta. (I:II = 37:5)									
Na saturation	2–1	—	2.0	16.0	23.0	31.02	4.36	4.94	17.54
Chemical treatment + trituration	2–1	—	1.51	1.48	15.27	41.81	6.20	7.3	26.43
Na saturation	1–0.5	—	1.02	9.6	13.5	39.8	8.79	9.34	18.66
Chemical treatment	1–0.5	—	0.95	4.72	12.56	44.32	6.96	11.81	20.86
Chemical treatment + trituration	1–0.5	—	—	—	12.64	40.74	7.42	8.17	26.31
Dark-gray forest-steppe silty clay from Sverdlovsk region (I:II = 21.0:50.5)									
Na saturation	2	10.31	6.98	14.08	22.79	26.7	5.8	0.82	6.88
Chemical treatment + trituration	2	—	1.5	11.38	14.63	30.9	6.9	10.4	24.10
Na saturation	2–1	10.24	6.4	13.3	16.5	34.8	6.2	0.99	6.7
Chemical treatment + trituration	2–1	—	0.85	15.34	16.79	36.35	9.2	11.3	10.1
Na saturation	1–0.5	8.87	7.67	11.0	20.5	29.9	6.2	1.78	7.3
Chemical treatment	1–0.5	—	0.53	14.18	12.54	41.37	10.36	11.72	9.3
Chemical treatment + trituration	1–0.5	—	—	—	3.58	23.62	8.77	18.5	36.32

gates are formed in soils by coherence of the group II particles by means of the surface adsorption of colloids on which sodium cannot exert any dispersing effect. But if these aggregates are subjected to even faint mechanical dispersion, that is, a strong jet from a wash bottle, then on drying out they, too, can cohere as a result of the liberation of a large quantity of clay.

A difference in quality of water-stable aggregates, depending on the ratio in them of group I and II particles less than 0.01 mm. diameter, is also noticeably reflected in some of the soil's physical properties. For example, the consistence or mechanical stability of the soil, determining the ease or difficulty of tilling it by agricultural implements, depends in many respects on its composition with respect to groups I and II. Up to the present time it has been considered that soil consistence is determined basically by its texture. However, according to our experimental data the consistence is far from being determined by the total content of particles less than 0.01 mm. diameter: it depends in many respects on the quality of these particles. Thus, in the thick fine-texture clay loam chernozem of Voronezh region having a 6.4% content of group II particles, test cylinders failed at loads of 14 kg./cm.^{2}, but in dark-gray forest-steppe soil containing 50.5% of group II particles failure occurred at loads of 1.9 kg./cm.^{2}, although the content of particles less than 0.01 mm. diameter was almost the same in both types according to the particle size analysis.

All the information presented shows convincingly that determining the composition by groups of the soil particles by Tyulin's method makes possible a new approach to the estimation of the agronomic value of water-stable aggregates and consequently to the evaluation of certain agronomic properties and of the soil structure.

Conclusions

1. The quality of the soil structure is determined not only by the total content of water-stable aggregates but also by their content of group I and II particles less than 0.01 mm. diameter by Tyulin's method.

2. Soils with a preponderance of group II particles are distinguished by a higher content of water-stable aggregates. Further, the clay and colloids in such soils are more firmly fixed to the soil particles and give firmer aggregates. The

fine (<1 mm. diameter) fractions of these aggregates are not only water-stable, but also resistant to the action of sodium ions.

3. It was established that coarse silt (0.05 to 0.01 mm. diameter particles), which often predominate in the texture of many soils, can be aggregated into coarse water-stable units and that they are thus aggregated in large quantities in soils with a high content of group II particles.

4. The consistence or mechanical stability of soils decreases as their content of group II particles increases, other factors being equal.

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DISTINCTIVE FEATURES OF THE PERCOLATION PROPERTIES OF SOILS AND SUSPENDED MATTER IN THE AMU-DAR'YA RIVER

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The hydrophysical properties of soils assume vast importance under irrigated farming conditions. Sometimes they interfere with the successful operation of agriculture and may contribute to salinization, rapid leaching of nutrients and fertilizers and so forth. In many regions irrigated by turbid water (deltas, flood-plains, alluvial plains) the soils are formed on stratified subsoils. The permeability of such soils are unusual and have not been extensively studied. To characterize all the distinctive permeability properties we experimented in the laboratory. Our investigations clarified the character and degree of influence of various factors on percolation which, in the region under study (the lower delta of the Amu-Dar'ya), include stratification of the soils along the profile, their microaggregation and distinctive features of mineralogical composition and physicochemical properties.

In the widely used methods for the laboratory investigation of permeability to water (1, 2, 14, 16, 17), it is recommended that the samples of water be applied from above at a previously fixed pressure using the principle of Mariotte's bottle. A number of investigators object to this means of supplying water because it produces phenomena affecting the percolation rate. Thus, Makridin (10) states that when the water is applied from above capillary action interrupts (beaded) filling of the pores, whereas with application from below the air from the sample is displaced by the mass of rising capillary menisci, as a result of which a continuous body of water is formed. Korzun (6) also refers to the resistance of the air compressed in the capillary pores to the free movement of water. When the water enters rapidly from above, the soil aggregates are destroyed by the air forced out by them and permeability is affected (11, 13). Furthermore, when water is applied to the monolith from above seepage often begins before all the soil is completely saturated. Polynov (12) has referred to this phenomenon which he explains by the presence of fissures, root channels, and so forth in the soil.

However, when water is applied to the sample from below the first drop to seep through indicates complete saturation of all the soil. When water is applied from below with minimal pressure, there is less dispersion of the soil aggregates and silting of the spaces between the larger aggregates.

Russel's apparatus (18), improved by V. M. Gotikov (Fig. 1), was adapted for the investigation of the percolation of loosely poured soil samples with application of the water from below. The apparatus uses the principle of communicating vessels allowing the investigation of the percolation at a definite head of pressure. This apparatus is extremely simple and convenient for investigating percolation under laboratory conditions. Among the advantages of the apparatus is the possibility of investigating several samples simultaneously over a long period of time and of determining the absorption rate and water permeability of the soil.

The soil sample is placed in a tube with a porous (fritted) bottom. Above, a large-pored porcelain plate or metal grid is placed on the sample, the plate is tightened by a glass tube which passes through a rubber tube fitted to the tube. The long bent end of the glass tube is placed over the receiving beaker.

Our experiments were all carried out on small quantities of material. We usually investigated the percolation rate through a layer 5 to 10 mm. thick. In a number of cases the position of this material corresponded to the structure of stratified irrigated allúvium and enabled us to clarify the nature of the changes in percolation rate caused by this structure. The materials we investigated were suspended matter and irrigated soils located in the lower Amu-Dar'ya delta at the Chimbaysk oasis. The percolation of subsoils consisting of thin layers of various textures have been studied by a number of investigators (4, 5, 7, 13, 15). However, they failed to state either the quality of the material used or the size of the particles comprising the layer, nor did they elucidate the principles governing

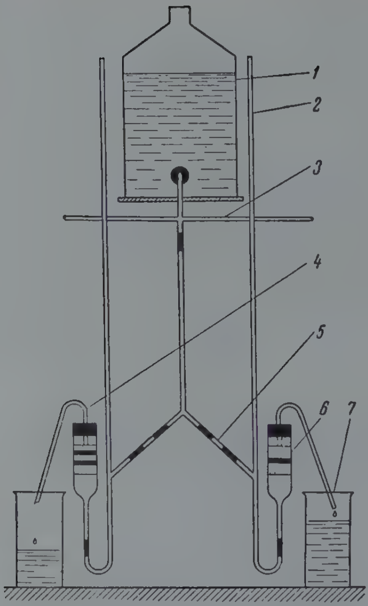

FIG. 1.—Russel's apparatus used for determining the percolation rate. 1—Bottle with tube for water; 2—long tube preventing overflow of water; 3—distributing tube with branches; 4—tube for leading off the filtrate; 5—capillary tube; 6—tube with sample being tested; 7—receiver.

changes in percolation rate owing to changes in layer thickness, and so forth.

According to Lebedev (9), when peat and sand are arranged in layers the permeability coefficient decreases considerably compared to that of peat alone or of sand alone. In Lebedevs' view, the cause of the decreased percolation rate in stratified material is the marked increase in moisture of the fine-grained layer when it is underlain by a coarse-grained one. If a fine-grained mineral lies under compact rock with percolation its moisture content will be lower than in the layer mentioned above.

TABLE 1

Changes in percolation rate varying with the thickness and number of layers

Diameter of fraction, mm.	Thickness of layer, mm.	Number of layers	Percolation rate, ml./hr.
0.001–0.005	5	1	15.0
same	10	1	6.1
same	5	2[a]	4.0
same	5	3[a]	1.0
0.005–0.01	5	1	64.0
same	10	1	42.5
same	15	1	34.4
same	5	2[a]	30.7
same	5	3[a]	14.0

[a] The layers in these experiments were separated by a layer of coarse-grained sand.

The soils of the Amu-Dar'ya delta, composed of suspended river material, are characterized by alternations of strata differing from one another in texture. We studied the effect of stratification on changes in the percolation rate. As subjects for the study we used fractions of a definite size isolated from suspensions and soils. The experiment showed that percolation through two 5 mm. layers, one of which consisted of 0.001 to 0.005 mm. diameter particles and the other of 0.005 to 0.01 mm. diameter particles, takes place at a rate of 14.6 millimeters per hour, that is, it corresponds closely to the percolation rate through a single 5 mm. layer of the 0.001 to 0.005 mm. diameter fraction (15 millimeters per hour). But if the 0.001 to 0.005 mm. and the 0.005 to 0.01 mm. fractions are mixed in a 1:1 ratio and used to form a layer 10 mm. thick, its percolation rate is 22 millimeters per hour, that is, the rate increased by one-third in comparison with that of the preceding experiment.

An investigation of the percolation rate through stratified material consisting of one, two and three layers of particles all the same size showed (Table 1) that stratification considerably decreased the percolation rate, the greatest decrease occurring in the layers made up of finer particles. Thus, each successive 5 mm. layer of the 0.001 to 0.005 mm., diameter fraction caused a fourfold decrease in the percolation rate, whereas with the 0.005 to 0.01 mm. diameter fraction the decrease was only twofold. When these fractions were underlain by a compact mass instead of by a layer, a decrease in the percolation rate occurred when they were increased in thickness. However, the decrease was considerably less, especially in the coarser (0.005 to 0.01 mm. diameter) fraction, where tripling the thickness of the layer (to 15 mm.) gave a higher rate than for the two 5 mm. layers.

We succeeded not only in confirming experimentally the observations of A. F. Lebedev and of others, but also in discovering certain qualitative and quantitative principles governing changes in the percolation rates of stratified filtration material. Besides valuable theoretical considerations the results also enabled us to draw some practical conclusions. A stratified arrangement of soils in a delta sharply impairs their water permeability. Fine-textured strata are particularly dangerous. Disturbance of the stratification with various implements (chisel cultivators, "keliferi," and so forth) should improve the hydrophysical properties of these soils. Timely loosening of the soil before each watering will also improve infiltration.

In order to discover the relation between percolation rate and soil texture, an experiment was set up with natural soils taken from various depths and differing in texture. Soluble salts and carbonates had previously been removed from them. The results are given in Table 2, where the samples are listed in order of increasing fineness of texture.

Table 2 shows the direct influence of soil texture on the percolation rate of soils whose salts have previously been leached out. The data in this table are shown for the general characterization of soil types and can be used as a standard for comparison with other experimental data given in this paper. Moreover, the regular pattern of the change of percolation rate with variations in texture confirms the possibility of using this much quicker method to determine the texture of soils processed in an appropriate fashion.

The following experiment was set up to discover the percolation capacity of fractions of different-sized particles of suspended matter so as to reveal the limit of fineness at which percolation is sharply impaired. Determinations of the percolation rate through various fractions in layers of uniform thickness are shown in Table 3.

Table 3 shows that as the fraction grows coarser the percolation rate increases. There are especially large differences in the percolation between the <0.001, 0.001 to 0.005 and 0.005 to 0.01 mm. diameter fractions. Further increase in particle size have less effect on the percolation rate. This leads us to believe that the deposition of sediment consisting preponderantly of particles <0.005 mm. diameter will cause sharp impairment of the water permeability of irrigated soils, and the fraction <0.005 mm. diameter is the limit of granular fineness with an unfavorable effect on the percolation rate.

Sixty percent of the suspended matter of the Amu-Dar'ya is composed of particle diameters >0.005 mm. However, at the edges of the canal and in the irrigation ditches within the collective farms their content falls to 20 to 30%. This fact suggests that the sedimentation of considerable quantities of particles >0.005 mm. diameter takes place beforehand in the larger links of the irrigation net. The particles >0.005 mm. diameters are considered hydrographically "harmful" because they constitute the greater part of the alluvium thrown out of the canals when they are dredged. They form enormous mounds along the canal banks. The favorable percolation properties of these fractions can substantially improve the hydrophysical properties of the fine-textured irrigated soil that is often encountered in the oasis being investigated. To determine the possibility of using this material for sanding fine textured soils, we set up an experiment to change the percolation rate by the addition of different quantities of the fractions >0.005 mm. diameters. For the subject of the experiment we used the 0 to 22 cm. horizon of section 4 (medium clay loam). The experiment showed that transferring the material dredged from the canals (which consists preponderantly of particles >0.005 mm. diameters) to the fields exerts the same action in improving the percolation of the soil as does sanding them with coarser fractions consisting of medium sand alone.

TABLE 2

Changes in percolation rate of soils varying with the content of particles <0.01 and 0.001 mm. in diameter

Sample	Depth of horizon, cm.	Thickness of layer, mm.	Content of particles, %		Percolation rate, ml./hr.	Soil texture (Kachinskiy)
			<0.01	<0.001		
Section 4	22–41	5	17.4	7.58	42.0	Sandy loam
same	41–63	5	28.3	10.48	37.0	Sandy loam
Section 3	63–77	5	31.0	12.0	34.0	Silt loam
same	0–5	5	48.0	20.0	14.0	Loam

TABLE 3

Changes in percolation rate varying with the fraction diameter

Diameter of fraction, mm.	Thickness of layer, mm.	Percolation rate, ml./hr.
<0.001	5	1.2
0.001–0.005	5	15.0
0.005–0.01	5	64.0
0.01–0.1	5	67.8

Successive increases in the amount of the fraction >0.005 mm. diameter cause corresponding

TABLE 4

Effect of adding sand to soil on percolation rate (irrigated farm soil, Section 4, 0 to 22 cm. horizon)

Ratio in %: soil	Percolation rate in ml./hr. through layer 10 mm. thick
Fraction >0.005 mm.	
100:0	24.3
90:10	28.0
80:20	32.0
70:30	39.0
60:40	47.0
50:50	67.0

increases in the percolation rate (Table 4). The most abrupt and definite increase in the filtration rate occurs only when the soil fraction >0.005 mm. ratio is 50%; this corresponds to the percolation rate through a layer consisting only of the fraction >0.005 mm.

This suggests the desirability of transferring to the fields the matter dredged from the canals but in quantities not exceeding 50% of the weight of the soil being treated. Its effectiveness in improving the hydrophysical properties of irrigated soils is the same as that produced by applying sand alone, but river sediment is richer in nutrients than is sand. In the soil samples we studied the analytical data from the water extract showed the absence of salinization, and we did not investigate the effect of this factor.

A characteristic property of all the soils of Central Asia is their high carbonate content—up to 8% CO_2. A. N. Rozanov states that carbonates cause the occurrence of mircoaggregates, which, in turn, should exert a definite influence on the percolation of the soil. Large quantities of carbonates are also contained in the suspended matter of rivers. It can be assumed that the cementing action of carbonates will also appear in suspended material transported in irrigation water. To establish the microaggregation of suspended material and its effect, we investigated ten millimeter layers of intact soil and suspended material and also layers of soil and suspended material treated with weak HCl or made into a thick paste by grinding with a rubber pestle while moist (this treatment was carried out to destroy the carbonates). The results of the experiment are shown in Table 5.

TABLE 5

Effect of microaggregation on percolation

Sample	Percolation rate in ml. per hour through 10 mm. layer		
	Untreated	Treated with weak HCl	Ground with pestle
Irrigated farm soil, Section 4, 0 to 22 cm. horizon	24.3	13.1	9.5
Suspended material from the Kyzketken canal (right bank of the Amu-Dar'ya delta)	18.0	11.0	8.0

Table 5 shows that microaggregation improves the percolation of soils and suspended matter by a factor of about 2. Microaggregates are also present in suspended material, as may be seen from the comparative percolation rates before and after treatment with weak HCl. The samples which were ground had a somewhat lower percolation rate than those treated with weak HCl evidently because grinding destroys not only the microaggregates cemented by carbonates but other particles as well.

During the course of the experiments it was established that the percolation rate for the samples being investigated changed somewhat during the first few hours (Table 6).

Thus, for the fraction <0.001 mm. diameter, following the first three hours of the experiment, the decrease in rate reaches 20% of the initial rate, while for the fraction 0.001 to 0.005 mm. diameter the decrease is 7%. The decrease in filtration rate is more substantial for the finer fraction (<0.001 mm. diameter). This phenomenon enables us to assume that the cause of the decrease in percolation with time is related to the properties of the highly dispersed fraction (<0.001 mm. diameter) of the soils and alluvium. X-ray and thermographic analysis supported by complete chemical analysis established that the clay fraction of the investigated material is composed of hydromica and beidellite. Hydromica is marked by a certain capability of swelling in water. The presence of beidellite intensifies this property. Shown below are the swelling curves for the fractions 0.001 to 0.005 mm. and <0.001 mm. diameters (Fig. 2).

A comparison of the data from Table 6 and Fig. 2 reveals the relation between the swelling and the change in percolation rate with time. The percolation rate reaches a constant value three to four hours after the beginning of the

TABLE 6

Change with time in percolation rate through a 5 mm. layer composed of fractions <0.001 and 0.001 to 0.005 mm. diameter

Diameter of fraction, mm.	Thickness of layer, mm.	Percolation rate in ml. per hour							Decrease in rate as % of initial value
		Hours				Days			
		1	2	3	4	Second	Third	Fourth	
<0.001	5	1.5	1.3	1.3	1.2	1.2	1.2	1.2	20.0
0.001-0.005	5	16.1	15.7	15.3	15.0	15.0	15.0	15.0	7.0

experiment. By this time, however, the swelling process has largely stopped. The finely dispersed particles (<0.001 mm. diameter) swell more (14.4%) than the particles from the 0.001 to 0.005 mm. diameter (3.7%) so that the decrease in percolation rate is greater for the former.

Swelling generally causes a marked change in the percolation of soils and may itself change depending on the material. Minerals of the montmorillonite group are known to swell considerably (sometimes more than 100% of their original size; "askanite" swells to 53.96%), whereas minerals of the kaolinite group swell considerably less—up to 4.5%. The mineralogical composition of the soils and especially of the clay fraction is of substantial importance because of its physicochemical properties. Investigating the percolation helps to interpret the physicochemical and hydrophysical properties of soils.

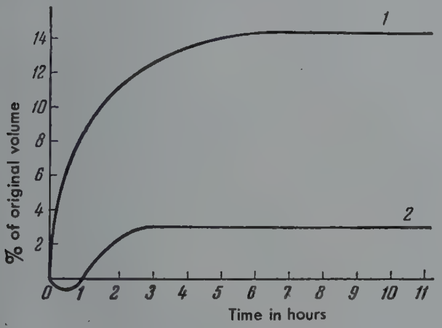

FIG. 2.—Curves of swelling for the particles <0.001 mm. and 0.001 to 0.005 mm. diameter from suspended matter and soils. 1—Fraction <0.001 mm.; 2—fraction 0.001 to 0.005 mm.

Conclusions

1. In the Amu-Dar'ya delta there is wide occurrence of soils having a stratified structure. Individual layers may exert an unfavorable effect on the agrophysical properties of the soil as a whole and in particular on water permeability. Destruction of this stratification by various means exerts a positive action on the permeability of the soil.

2. It has been established that the percolation rate decreases with increasing dispersion of the layer, its thickness, number of layers, and the time it takes for the water to seep through the soil.

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FIELD DETERMINATION OF THE STRUCTURAL CONDITION OF THE SOIL BY THE RATE OF CHANGE OF ITS PERMEABILITY TO AIR

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In 1951 we worked out a field method to investigate the condition of the soil structure by means of a portable apparatus. This method was based on the principle of successive determinations, first of the permeability of the soil to air at field capacity and then after moistening it with a definite amount of water.

In soil of unstable structure, moistening with water leads to destruction of the aggregates and to an abrupt and long-lasting reduction of permeability to air. In soil with a water-stable structure the water is quickly absorbed into the pores of the aggregates without destroying them and in an hour the permeability to air is reestablished at a high level.

The investigation of the soil structural condition is carried out directly on the field using a selected 6 to 8 m.^{2} area at the edge of which the apparatus (Fig. 1) is set up on three removable legs (Fig. 1, *5*). Into the thin-walled cylinder (*12*) with a cross-sectional area of 25 cm.^{2} ($d = 56.5$ mm., $1 = 105$ mm.), having an open cutting edge below and a closed upper part from which a nipple projects, a perforated disc (*16*) is placed with the pins pointing upward. The disc is to keep the upper opening of the cylinder from being blocked by soil and the surface of the soil from being washed away by water. To keep separate the space immediately adjoining the inner wall of the cylinder, the inner edge of the cylinder receives a 2-mm.-thick ring of lubricating grease which, when the cylinder is pressed into the ground, is distributed evenly over its walls. By using the handle (*11*) the assembled cylinder is pressed into the soil to a depth of 10 cm. so that the soil surface reaches the perforated disc. The cylinders are distributed in four or five rows of three cylinders over the area being investigated.

An initial flow of air of 100 milliliters per minute is established in the apparatus with the three-way stopcock (*4*) set for connection to the atmosphere. To do this, water is cautiously released from the narrow reservoir-pail (*6*) into a constant-pressure device (*1*) from which a part of it flows into the air-pressure regulator (*2*) while the excess flows off into a small pail (*7*). By moving the air-pressure regulator gradually up the pole (*9*) a constant level of the meniscus is reached at the 100 milliliters per minute mark in the right branch of the flowmeter. Care must be taken, especially at the beginning of the procedure, to see that the wall of the rubber tube connecting the constant-pressure device (*1*) with the air-pressure regulator (*2*) is completely wet: to do this the tube is squeezed by hand until all the air bubbles have been removed. Before every determination of the air permeability of the soil the setting of 100 milliliters per minute for the initial rate of flow of air should be checked with the stopcock (*4*) turned to communicate with the atmosphere.

First a determination is made of the permeability to air of the soil at field capacity. For this purpose the free end of the three-meter-long thick-walled rubber tube leading from the stopcock (*4*) is attached successively and in a definite order to the tubular projection from the tops of the cylinders (*12*) which have been plunged into the ground. After the initial rate of airflow into the atmosphere has been set, stopcock (*4*) is turned to direct the airflow into the soil and the level of the meniscus in the flowmeter (*3*) is read.

When the air-pressure regulator (*2*) has been filled to three fourths of its capacity, the access of water from the reservoir (*6*) is stopped at once and the water is drained through a tubular opening or a siphon mounted in the stopper into the lower pail, (*7*) after stopcock (*10*) has been turned to connect with the atmosphere. As the water accumulates in pail (*7*) it is transferred to the upper reservoir (*6*). In practice 9 to 10 liters of water will last for an entire working day, including that used for moistening the soil in the cylinders.

After the determination of the permeability to

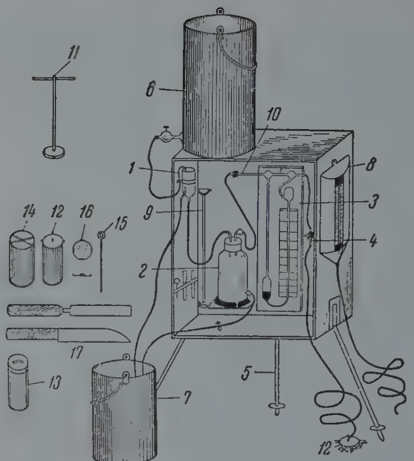

FIG. 1.—Apparatus for field determination of the air permeability of soil by N. F. Dobryakov.

air at field capacity, 50 milliliters of water is poured into the same cylinders in the ground, one after another, from container (*8*), giving a layer 20 mm. thick in the cylinders. The container (*8*) is provided with a water gauge in the form of a tube behind which is a scale calibrated at every 25 and 50 milliliters; it is suspended on the outside of the right side of the apparatus with its lower edge 60 cm. from the surface of the ground. The addition of water to the cylinders takes place continuously in the same order as in the first determination of the permeability to air. The time at which the addition of water to the first cylinder was begun is noted in the field notebook to establish the time for the subsequent determinations of the permeability to air.

When the water is added to the cylinders, the rate of its absorption by the soil is determined with a stopwatch. After a signal from an assistant that the water-conducting tube has been connected to the next cylinder, the investigator releases the spring pinchcock on the tube and simultaneously starts the stopwatch. When the water level in the gauge of container (*8*) reaches the next 50 ml. mark the flow of water and the stopwatch are both stopped. From the total time required to moisten the soil in all the cylinders, the mean rate of absorption of water by the soil in seconds (M) and the standard error of the mean (±m) are calculated. The higher the absorption rate of water by the soil, the better the condition of the soil structure usually is.

If the water is rapidly absorbed by the soil then the first of the determinations of the permeability of the soil to air in all the cylinders in turn takes place five minutes after the moistening process has begun. The second series of determinations is made 15 minutes, the third 30 minutes and the last 60 minutes after the beginning of the addition of water to the first cylinder. When the water is slowly absorbed (as often occurs in structureless soils), the first series of permeability determinations is made 15 minutes and the others 30 and 60 minutes after moistening.

During the half-hour interval before the last permeability determination, the cylinders numbered (*12*) and (*14*) in Fig. 1 are used to take soil samples for field capacity determinations. The samples are placed in the usual containers.

When the procedure is finished for this particular area, the cylinders are removed with the handle (*11*) and freed of soil by the use of the knife and chisel (*17*). The perforated discs are pushed out of the cylinders with the long pin (*15*) following which the cylinders are wiped off inside and out with rags. Following insertion of clean discs and application of grease, the cylinders are ready for carrying out determinations at another point. When the apparatus is to be moved the cylinders are stacked vertically in reservoir (*7*) which is placed inside the pail (*6*). The small tank (*8*) with the gauge, the removable legs and the rubber tubes are placed

TABLE 1

Characterization of moist consistence and structural condition of soil by the rate of change of permeability to air

Consistence		Structural condition	
Permeability to air at field capacity, ml./min.	Degree of consistence	Permeability to air 60 min. after moistening with 20 mm. of water, ml./min.	Structural condition of soil
0–10	Extremely firm[a]	0–20	Structureless
10–30	Very firm	20–40	Weak
30–50	Firm	40–60	Moderate
50–70	Friable	above 60	Strong
70–90	Very friable	—	—
90–99	Loose		

[a] In our 1952 classification there was no "extremely firm" category.

inside the box, which is then closed by the front side inserted from the top. The handle (*11*) is fastened to the folding chair used when working with the apparatus.

The replication in the field investigation of the structural condition of the soil should be 12- to 15-fold depending on the number of cylinders used in the soil. From the arithmetic total, calculations are made of the average value of M and ±m for the first and last determinations of permeability to air; this makes it possible to establish the reliability of differences ($M_2 - M_1$) between areas under study.

This method permits determination of the permeability of soil to air in 12 to 15 cylinders in three to five minutes, while about an hour and a half is required for an entire cycle of the procedure, including moistening the soil. Thus, the investigator and his assistant can carry out determinations at five to six places per day, depending on the distance between them.

If desired, determinations may be made of the change rate of permeability to air not only in the surface soil, but also in the deeper soil horizons. In this case use is made of the cylinder numbered (*14*) in Fig. 1, which has a crosspiece for a handle at the upper end, to remove a 10- or 20-centimeter layer of soil. Then the original type of cylinder (*12*) is placed in the hole thus dug and the determination is carried out by the method described.

The degree of moist consistence and the structural condition are established according to the indices of permeability to air at field capacity and 60 minutes after moistening, as shown in the classification table. The table was worked out for sod-podzolic and gray forest soils having the texture of coarse, medium and fine clay loam.

Represented graphically, the data from field determinations give a visual conception of the stability of soil structure at various locations. Fig. 2 shows the results of investigations made in 1953 in a long experiment at the Dolgoprudnaya Agrochemical Experiment Station with quantities of lime applied a single time in 1926. The data given show that 27 years after liming, under a crop of oats sowed after grass in the first year of use, the soil in the modification of the experiment using 2.25 metric tons per hectare was very friable and was structureless. In modifications using larger quantities of lime—18 and 22.5 metric tons per hectare—the soil was characterized as loose and with a very strong structure. In a modification using 9 metric tons of lime per hectare the soil was said to be of friable consistence and of moderately durable structure.

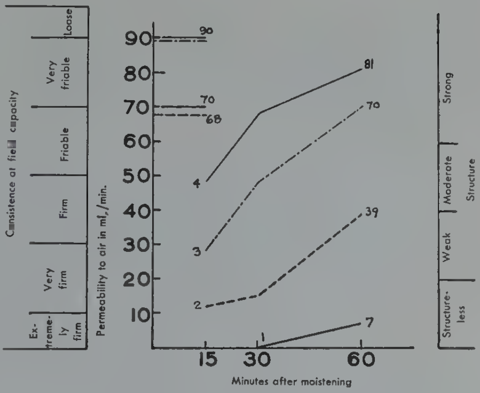

FIG. 2.—Structural condition of the soil under oats in crop rotation III. Dolgoprudnaya Agrochemical Experiment Station. Quantities of lime applied in metric tons per hectare: 1—2.25; 2—9; 3—22.5; 4—18.

By the use of the method described here, it was possible to show the effects of different quantities of lime and of the prolonged application of organic and mineral fertilizers under annual and perennial crops on the structural stability of sod-podzolic soils which it would not always have been possible to detect with other methods.

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A SIMPLIFIED METHOD FOR DETERMINING SOIL MOISTURE

A. P. Oganesyan

At the present time the literature contains numerous methods of determining soil moisture. Of these, the best known methods are the gravimetric (drying soil at 105° C.), pycnometric, carbide, electrometric, alcohol, tensiometric, and others.

However, in practice, the only generally accepted method is the gravimetric, in which soil samples are dried in special beakers in a drying oven at 105° C. for six hours with repeated drying to constant weight. The investigations of Gumenskii (3) indicate that this complicated method is not accurate.

It is known that moisture determinations on the largest scale are done to determine the right conditions for irrigation, for agrotechnical amelioration and for other purposes. However, since data from the gravimetric determination can best be obtained on the second day after taking samples, it is impractical to use. Further, research work urgently requires faster, easier, and more accurate methods of studying the properties of soil. In this respect, the "burning alcohol" method of Bouyoucos is advantageous. This author (7–9) perfected a method and proposed an apparatus of original construction for fast determination of soil moisture.

Bouyoucos' method was studied experimentally by many Soviet and foreign scientists who found serious discrepancies. For example, Kalashnikov (6), Ivanov (5), and Voskresenskii and Levina (1), state certain shortcomings of the burning alcohol method, but approve and recommend it for wide use. Grabovskii (2) and Doyarenko (4) consider the burning alcohol method generally unacceptable for studying soil moisture. Having generally investigated the method, the first group of authors (6, 5, 1) set for themselves more concrete tasks. Kalashnikov (6), trying to make moisture determinations by the alcohol method cheaper, found it possible to substitute for the ethyl alcohol used by Bouyoucos, methyl, propyl, denatured and wood alcohol. Voskresenskii and Levina (1) used this method for determining moisture when the soil contained a large amount of organic matter. However, all these investigators did not use Bouyoucos' original apparatus, and limited themselves only to the results obtained from their own simplifications of the apparatus, these results being compared with the data obtained by the gravimetric method.

According to Bouyoucos' method, a weighed sample of 20 to 25 grams of soil is placed in an elevated pan having legs and a perforated bottom. To keep the soil from coming through the holes, a circular piece of filter paper is laid under the sample; this also protects the soil from the flames of the burning alcohol which has been poured into the lower pan for repeated combustion. After all the alcohol has been burned, both pans are weighed at once, and to be sure that all the water has been extracted from the soil, 10 to 15 cm^3 of alcohol is again poured into the lower pan and burned. Bouyoucos recommends repeating this process until a constant weight is obtained, which by his method takes five to six ignitions of the sample. At the same time he points out that when the soil contains more than 12% organic matter, the results of the moisture determination are higher because of the partial combustion of organic matter; this is a basic limitation of his method.

Kalashnikov (6) showed that a humus content of 10.5 to 11% is the highest for which the test is valid. At higher percentages, the moisture determination gives incorrect results.

We tested the Bouyoucos method on a large number of samples of different types of soils by comparing the data with the results of parallel moisture determinations in a drying oven at 105° C.

The results (Table 1) show considerable deviations. When hygroscopic moisture is determined in triplicates, the deviations from the mean reach one percent and more, and the average deviation computed from 27 determinations is larger than 0.55. The comparable figure for the generally accepted method is 0.17. For soil samples with higher moisture content the discrepancies between parallel determinations reach 3 to 4%. Values on moisture in the upper humified soil horizons are higher as a rule, while for the lower horizons, poor in organic matter, they are somewhat lower. Discrepancies in the data are a result of the partial combustion of organic matter, of uneven heating of the sample and of partial burning of the filter paper.

Besides having these limitations, the Bouyoucos apparatus is awkward in its construction: the lid does not close tightly so the sample may lose moisture during the initial weighing and it may absorb moisture after the final drying. These lead to inaccuracy in moisture determination, especially when there is an interruption in the work.

These limitations are the main hindrances to wide application of the alcohol method of moisture determination, especially in the field. All these difficulties, especially the last, impelled us to seek means of eliminating them, so that this method might become simpler and more accurate and might be more widely applied.

We developed the model of the apparatus shown at the left in Fig. 1. The apparatus consists of an ordinary aluminum drying vessel, 38 mm. high and 50 mm. in diameter, in whose lid is placed a tripod covered by a metal screen with 0.1 mm. apertures. Soil does not sift through such a screen, so it is not necessary to lay a filter paper under it. This screen also has the advantage that it is not penetrated by flames originating from the alcohol which has dripped into the lower pan (in the vessel lid).

The tripod is made with a diameter 2 to 3 mm. smaller than that of the vessel's lid, which serves as a base and which during the procedure is weighed together with the tripod. The height of the latter must be 1 cm. higher than the sides of the base. Only in this way does the combustion proceed with a normal air intake, and the alcohol is used most economically and effectively. The tripod with the screen is compactly and conveniently assembled, and in case of interruptions in work or with wind (under field conditions), the sample and tripod are enclosed in the vessel. Weighing is also carried out this way.

Having studied the performance of the apparatus and its thermal relations in burning the alcohol, we feel that the construction described is efficient and technically convenient. It decreased the consumption of alcohol and produced more accurate data under both laboratory and field conditions.

TABLE 1

Comparative determinations of moisture by the oven drying and alcohol combustion methods

Soils	Sample depth, cm.	Organic matter, %	Determination of soil moisture, %					
			Oven drying method			Alcohol combustion method		
			Moisture %	Average	Deviation from average	Moisture %	Average	Deviation from average
Chernozem	0–18	6.37	6.37		+0.12	8.33		+0.52
			6.11	6.25	−0.14	7.05	7.81	−0.76
			6.28		+0.08	8.04		+0.23
	18–37	3.17	6.20		+0.09	7.84		+1.09
			6.00	6.11	−0.11	6.38	6.75	−0.37
			6.14		+0.03	6.03		−0.72
	37–63	2.05	5.28		−0.19	4.48		−0.91
			5.64	5.47	+0.17	6.65	5.39	+1.26
			5.49		+0.02	5.03		−0.36
Brown forest	2–12	6.76	4.51		+0.26	5.15		+0.39
			4.24	4.25	−0.01	4.22	4.76	−0.54
			4.00		−0.25	4.90		+0.14
	32–47	1.75	4.72		+0.34	3.92		−0.09
			4.05	4.38	−0.33	4.01		+0.24
			4.37		−0.01	3.87		−0.14
	46–68		4.27		−0.06	4.15		+0.23
			4.80	4.33	+0.47	3.84	3.92	−0.08
			3.93		−0.40	3.78		−0.14
Brown	0–20	1.36	2.85		0.00	4.44		+0.80
			2.67	2.85	−0.18	3.12	3.64	−0.18
			3.04		+0.19	3.35		+0.38
	20–32	1.07	2.23		−0.10	2.27		−0.10
			2.40	2.46	−0.06	2.01	2.37	−0.36
			2.69		+0.23	2.83		+0.46
	32–54	0.84	2.54		+0.10	1.68		−0.52
			2.36	2.44	−0.08	2.06	2.20	−0.14
			2.41		−0.03	2.86		+0.67
Average deviation					+0.17			+0.55

When determining moisture, a sample of 3 to 5 gm. of soil is laid in an even layer on the screen and quickly weighed. Then the soil is slowly and evenly saturated with alcohol until the first droplet runs off into the base. For such a degree of saturation, about 1 cm^3 of alcohol is consumed for each gram of soil. The alcohol burns for 1.5 to 2.0 minutes. Determinations showed that during the first burning of alcohol the temperature of the layer of air over the surface of

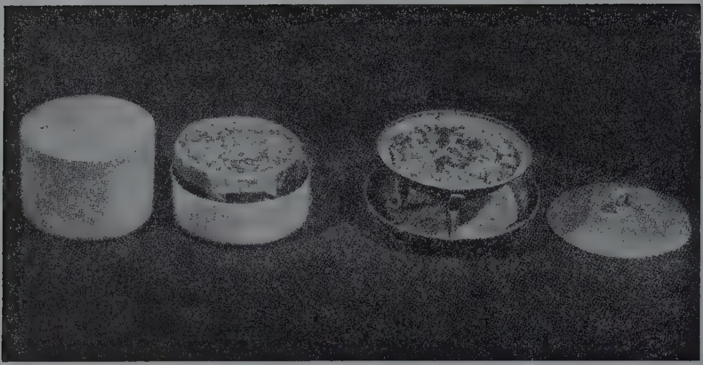

FIG. 1.—Apparatus with samples for moisture determination by the alcohol method: 1—on the right the Bouyoucus apparatus, spots of burned organic matter being visible; 2—on the left the apparatus we have proposed.

the soil reaches 150° to 160° C.; in the surface layer of the soil it goes up to 120° to 130° C.; in the center the temperature remains within the range of 90° to 100° C. and only at the end of the burning of all the alcohol does it rise for a few seconds to 110° to 120° C., after which it gradually falls off.

TABLE 2

Required successive dryings in the determination of soil moisture by the alcohol method

Soil	Sample depth, cm.	Sample, gm.	Loss of moisture at repeated dryings, gm.			Moisture		Average, %	According to drying oven data, moisture in %
			I	II	III	gm.	%		
Chernozem	0–21	3	0.16	0.21	0.21	0.21	7.26	—	—
		3	0.16	0.20	0.20	0.20	7.14	7.18	6.94
		3	0.16	0.19	0.20	0.20	7.14		
	105–156	3	0.15	0.16	0.16	0.16	5.63		
		3	0.14	0.15	0.15	0.15	5.28	5.40	5.66
		3	0.15	0.15	0.15	0.15	5.28		
Chestnut	0–18	3	0.12	0.14	0.14	0.14	4.90		
		3	0.13	1.13	0.13	0.13	4.52	4.64	4.75
		3	0.12	0.13	0.13	0.13	4.52		
Brown	0–17	3	0.09	0.11	0.11	0.11	3.80		
		3	0.10	0.10	0.10	0.10	3.45		
		3	0.11	0.11	0.11	0.11	3.80	3.68	3.56

At the second burning there are somewhat increased temperatures if all the moisture has already evaporated from the soil. It is seldom necessary to repeat the alcohol burning a third time. Generally, after the second burning all the moisture has evaporated from the soil. Data presented in Table 2 show the close agreement of parallel determinations, and twice is sufficient to carry them out. For two combustions the total consumption of alcohol for one moisture determination in air-dry soil is about 10 cm^3, while for the same determination by the Bouyoucos method, 100 to 120 cm^3 are used.

In order to be sure of the accuracy of the data obtained by applying the alcohol method to soil with a higher moisture content, trials were made of samples at field moisture. At the same time samples of chernozem soil were prepared with definite gradations of moisture and in these samples the moisture was determined by the generally accepted alcohol method described previously.

TABLE 3

Influence of the amount of initial moisture on the results of its determination by the alcohol method

Condition of the soil	Method of determination	Moisture of soil in %					
Artificial moistening	1) Given moisture	37.00	32.00	27.00	22.00	17.00	15.00
	2) Alcohol method	36.95	31.04	26.58	22.48	17.19	14.94
Field moisture	1) Oven drying	—	28.50	17.47	14.21	13.76	11.80
	2) Alcohol method	—	28.79	17.16	13.24	13.21	12.78

Table 3 shows that, starting from the field moisture capacity up to hygroscopic moisture, the results of moisture determination by the alcohol method agree with data obtained by the generally accepted drying oven method.

The amount of alcohol consumed (as was indicated in the discussion of the Bouyoucos method) almost fails to increase with increased moisture.

In working with the proposed apparatus, heating of the soil sample takes place more uniformly and does not form spots on the surface of the sample because of the partial combustion of organic matter. This effect is observed when working with the Bouyoucos apparatus (Fig. 1). To determine the moisture of one sample, 5 to 7 minutes are required and approximately 5 ml. of alcohol are consumed.

Speed of the determination, simplicity, and portability of the necessary equipment make the method convenient for use under a wide range of working conditions.

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A METHOD OF DETERMINING THE RESERVE OF AVAILABLE SOIL PHOSPHATES

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Utilization of labelled atoms to study the phosphate nutrition of plants and soil phosphates has been widely adopted during recent years.

In research by the Scientific Institute for Fertilizers, Insecticides and Fungicides the radioactive phosphorus isotope P^{32} is used both in experiments estimating the availability of various phosphates, and in experiments studying the conversion in soil of phosphorus fertilizers and the change and accumulation of available soil phosphates.

Beginning in 1952, we undertook pot experiments to determine the quantity of available phosphates in soil, using P^{32} in a minimum amount of water-soluble phosphate carrier and calculating the results of the experiment by the formula: $X = \frac{P \times 100}{K}$, where P is the plant's intake of unlabelled phosphorus and K is the percent utilization of P^{32}. Principles of the method used in such experiments were reported by Sokolov (4).

In the research of Fried and Dean (5), the total available phosphorus was computed by the formula: $A = \frac{B(1-y)}{y}$, where A is the amount of available phosphorus in the soil; B is the amount of fertilizer in labelled form; and y is the portion of the total phosphorus content in the plant which is labelled. Murdock and Seav (6) show that the amount of fertilizer alters the A value; therefore it is necessary to set up experiments with minimum applications of labelled fertilizer.

Absolute values of plant intake of labelled and unlabelled phosphorus depend on various conditions in carrying out the pot experiment. But the ratio between the amounts of marked and unmarked phosphorus taken in by the plants must have a more constant value—this ratio is also basic to the determination of the total amount of available soil phosphates. Thus, an absolute measure of the total amount of available phosphates is a more stable indicator than the utilization coefficient of labelled phosphorus. Comparable data for the latter may be obtained only under rigidly defined standardized conditions of experimentation, which must be developed.

When fertilizers are applied, the utilization of soil phosphates is altered; therefore, the use of labelled phosphorus in a minimum amount of carrier guarantees production of more stable indications of the amount of the total available phosphates. In this case, the values for the total available phosphate obtained by the formulas of Larsen, Fried and Dean and of Sokolov concur, since the formula of Larsen, Fried and Dean gives the same A value as the formula of Sokolov; but the difference between them is that when computing the total available phosphates by Larsen's formula it is not necessary to know the utilization coefficient of labelled phosphorus and the total phosphorus intake by the plants in the experiment; only one analysis of an average sample crop for P_2O_5 and the activity is sufficient. By these measures, regardless of the size of the crop, the value for the total of available phosphates is calculated. This is the shortcoming of the Fried and Dean formula (5), since investigations show that the size of the reserve without the value for K insufficiently characterizes the phosphate condition of the soil.

In the report by R. S. Russel, et al. (7), a negative attitude was expressed toward determining the total available soil phosphates by the method of Larsen, Fried and Dean, since the value obtained does not give an accurate idea of the phosphate nutrition of the plants. Also, one value for the reserve cannot give such an idea; it must be supplemented by the characteristic mobility of this reserve. However, we cannot deny the importance of this value since it gives information about soil phosphates. Within one type of soil this value may also be used for solving practical questions.

Table 1 presents the results of an experiment with oats to which various applications of phosphates were made. In the experiments a decrease in the utilization of soil phosphates took place as fertilizers were applied. Consequently, a minimal amount of labelled phosphate, one which does not impinge on the utilization of soil phosphates, seems to be the first condition for an exact determination of the total available soil phosphates.

A uniform distribution of phosphates in the soil which does not create foci of various degrees of phosphate availability is the second condition. This is achieved by carefully stirring the fertilizer, necessarily applied in water-soluble form, into the soil.

The plants make the same use of both the labelled phosphorus and those soil phosphates into which the applied water-soluble labelled phosphate is converted as a result of interacting with the soil. Processes of phosphate solution and precipitation occur in which a negligible amount of labelled phosphorus, which does not influence these processes, takes part. The labelled phosphorus is distributed between the soil phases in the same way as the mobilized soil phosphates; consequently it serves as an indicator of these processes. Finally, in the soil continuous processes can and do occur which convert phosphates into difficultly soluble compounds, which under these experimental conditions are not detected by labelled phosphate. But the processes of secondary phosphate precipitation, adsorption and reformation are described by labelled phosphate.

The ratio of the total activity of the crop to the applied activity of the fertilizer, expressed in percentages, is the utilization coefficient of labelled phosphorus. It describes the mobility of the soil phosphates and shows the utilization of the total available soil phosphates in the experiment.

In order to determine the total available soil phosphates, a pot experiment was set up in which the soil was diluted with sand. The computation was carried out by the Sokolov formula. For the calculation, from the total phosphorus content of the plants, the average phosphorus content of the seeds was calculated in order to take into account the assimilation of soil phosphates only. The soil is diluted with stand so that the extraction of available phosphates from the soil may be as complete as possible. Analysis of the sand for phosphorus showed negligible amounts. For the experiment the following soils were taken: sod medium–podzolic soil (pH of salt extract 4), thick chernozem, typical sierozem, and krasnozem.

TABLE 1

Influence of the application of fertilizers on the utilization of soil phosphates

Plan of the experiment, P_2O_5 per pot, mg.	Crop per pot, gm.	Recovery of P_2O_5 by the plants per pot, mg.			
		P^{31}	P^{32}	Intake of fertilizers by difference	Intake of soil phosphates
Podzolic soil					
NK	11.22	20.10	—	—	20.10
NK + 250 mg. P_2O_5	18.68	60.30	46.74	40.16	13.56
Podzolic soil plus 22.5 metric tons per hectare of lime					
NK	13.27	22.14	—	—	22.14
NK + 50 mg. P_2O_5	16.43	37.19	13.64	15.03	23.55
NK + 100 mg. P_2O_5	17.50	45.26	28.02	22.15	17.24
Chernozem					
NK	15.19	12.91	—	—	12.91
NK + 50 mg. P_2O_5	17.50	26.11	12.64	13.20	13.47
NK + 100 mg. P_2O_5	21.21	42.20	29.81	29.29	12.39
Sierozem					
NK	14.60	17.81	—	—	17.81
NK + 250 mg. P_2O_5	17.85	74.38	68.10	56.62	11.48

Plan of the experiment:

1) One unit of labelled soil
2) ½ unit labelled soil plus sand
3) ¼ unit labelled soil plus sand
4) ⅛ unit labelled soil plus sand

Radioactive phosphate at less than 1 mg. of P_2O_5 per pot, with an activity of 100 microcuries, was carefully mixed with soil and left for three days, after which the pots were filled. A pot contained 3 kg. of podzolic soil or sierozem, 2.8 kg. of chernozem, or 2.2 kg. of krasnozem. A constant amount of nitrogen and potassium ($NH_4 \cdot NO_3 + KNO_3$) was introduced into all the pots at 0.5 grams of N, 0.5 grams of K_2O, and 1 gram of $MgSO_4$ per pot. The experiment is duplicated. Oats of the Dippe variety are used for the experiment, the sowing having been carried out with germinating seeds which were first disinfected with NIUIF-2 (2.5% ethylmercuric chloride or bromide). Twenty-six plants were left in each pot. During the growing period they were watered with distilled water up to 70% of total soil moisture capacity, taking into account the moisture capacity of the sand. Harvesting was carried out in the blooming phase. The plants exhibited signs of phosphate starvation in the krasnozem experiment and when the soil was diluted 4:1 and 8:1 with sand. The yield of green vegetation was also markedly less in these treatments. The green tops and the roots were gathered and analyzed separately. The experimental error mp was ±0.56 grams per pot. The roots were washed with a solution of $Ca(H_2 \cdot PO_4)_2 \cdot 2H_2O$ containing about 5 grams of the salt per liter of solution, since it was supposed that adsorption of P^{32} at the surface of the roots was possible. However, after the washing the solution did not show radioactivity. The activity and total phosphorus content in the green tops and roots were determined after they had been dried and ground. On this basis the coefficient of P^{32} utilization and the reserve of available soil phosphates were calculated. The total phosphorus in the plants was determined by dry ashing with calcium acetate, followed by determination by the Shmuk modification of the Denige's procedure on the photocolorimeter. The activity of a sample of 0.2 grams of dry vegetable matter was determined, with subsequent recalculation for the entire crop. Data from the analysis are presented in Table 2.

The utilization coefficient of labelled phosphorus, in general, varied little when the soil was diluted with sand. In the test of podzolic soil the largest utilization coefficient was obtained without dilution, but possibly this was a coincidence. The highest utilization coefficient of labelled phosphorus was obtained in the sierozem test. The test of krasnozem revealed an extremely low utilization coefficient which increased with dilution. The phosphorus content of the crop was proportional to the quantity of soil, with the exception of the smallest portion of soil (⅛th) where the figures were 1 to 2 mg. higher than expected. This may be explained by the abrupt change of phosphate nutrition: when there is a large dilution, assimilation of less mobile forms of phosphates is possible and also, the intake of 1 to 2 mg. P_2O_5 is within the limits of accuracy of the experiment.

The reserve of available phosphates corresponds in general to the quantity of soil introduced except in the case of podzolic soil, where for a 50% dilution, the size of the reserve is not halved. But if one takes the average utilization coefficient of labelled phosphorus, the reserve will correspond to the dilution. For the greatest dilution of soil (⅛th), the size of the reserve obtained was somewhat higher, which is explained by the assimilation of a large amount of phosphates by the plants.

For podzolic soil, chernozem and sierozem the quantity of available phosphorus corresponds to the amount of soil introduced.

The reserve of available phosphates proved to be very high in the case of krasnozem. Krasnozem, as is well known, contains phosphates in a relatively unavailable form to plants (1). This clearly shows that to determine the characteristics of the soil phosphate condition, it is not enough to calculate the total reserve phosphates. It is also necessary to consider the utilization co-

TABLE 2

Available phosphate reserves in the soils and percent utilization of soil phosphorus in an experiment with soil diluted by sand

Soils	Type of determination	Quantity of soil in the experiment, %			
		100	50	25	12.5
Podzolic	Percent utilization of P^{32}	13.97 (11.18)	10.75	9.60	10.40
	Mg. of P_2O_5 in harvest	31.27	16.17	6.42	5.11
	Available P_2O_5 reserve in soil, mg.	224(280)	150	67	49
Chernozem	Percent utilization of P^{32}	17.44	16.15	17.36	15.20
	Mg. of P_2O_5 in harvest	59.79	26.47	16.64	9.52
	Available P_2O_5 reserve in soil, mg.	343	164	96	63
Sierozem	Percent utilization of P^{32}	22.44	24.78	19.71	26.41
	Mg. of P_2O_5 in harvest	42.50	22.15	11.37	8.31
	Available P_2O_5 reserve in soil, mg.	189	89	58	32
Red soil	Percent utilization of P^{32}	0.67	1.02	1.20	1.36
	Mg. of P_2O_5 in harvest	2.18	3.12	1.44	1.42
	Available P_2O_5 reserve in soil, mg.	326	306	121	105

efficient, which expresses the degree of soil phosphate mobility and the utilization of reserves in the course of the experiment. When there is a large total reserve of available phosphates in krasnozem, the degree of their mobility is extremely low, in agreement with generally accepted ideas about krasnozem. The presence of the large reserve of relatively immobile but still available phosphates has not attracted attention.

Table 3 presents these same data in a recalculation per 100 grams of soil in which the phosphate condition of the investigated soils is characterized. The figures given are averages for the four experimental treatments. For sierozem, with the highest utilization coefficient, the phosphate reserve is lower than for podzolic soil and chernozem. This confirms the mobility of sierozem phosphates; with a small total reserve they are easily utilized by plants. In krasnozems with a large total phosphate reserve, the degree of mobility is quite low, consequently the phosphates of krasnozem are little used by plants. This leads to the conclusion that in sierozem even small applications of phosphorus fertilization will be effective, since they will be easily utilized by plants; in krasnozem large applications of fertilizer will be necessary in order to secure the required amount of phosphates. Finally, this applies only to broadcast application of phosphates when they are evenly distributed in the soil. When applied locally, phosphates do not react with the bulk of the soil, and the degree of their availability will differ from the case in which they are evenly distributed in the soil.

In the present experiment, the minimum quantity of labelled phosphorus applied had no effect on the intake of soil phosphates. Therefore it was possible to form an opinion of the utilization and mobility of soil phosphates from the utilization of labelled phosphorus. The size of the reserve decreased in proportion to the quantity of the soil. Consequently, the size of the reserve in the present case gives the amount of available soil phosphates with adequate accuracy.

The results of a pot experiment with peas are presented for comparison. Here, different quantities of labelled phosphorus fertilizers were applied (Table 4).

TABLE 3

Characteristics of the phosphate condition of various soils

Soils	Utilization of P^{32}, %	Recovery of P_2O_5 in the harvest	Store of available phosphate reserves, mg./100 gm. of soil
Podzolic	11.2	1.1	9.7
Chernozem	16.5	2.3	13.8
Sierozem	23.3	1.6	7.1
Krasnozem	1.06	0.3	27.4

TABLE 4

Determination of the available phosphate reserves in soils when various applications of labelled fertilizer are made (P_2O_5 in mg./100 gm. of soil)

Plan of the experiment	Recovery of P_2O_5 in the crop	Utilization of P^{32}, %	Available phosphates in applied fertilizers	Available phosphate reserves in soil
Podzolic				
NK	0.46	—	—	—
NK + 10 mg. P_2O_5	0.54	0.9	60.0	58.0
NK + 100 mg. P_2O_5	1.22	3.05	40.0	28.3
NK + 1000 mg. P_2O_5	7.56	5.31	142.6	25.0
Podzolic plus 22.5 metric tons per hectare of lime				
NK	1.86	—	—	—
NK + 10 mg. P_2O_5	2.00	7.70	25.9	24.7
NK + 100 mg. P_2O_5	4.23	17.59	24.2	12.4
NK + 1000 mg. P_2O_5	10.31	7.79	132.4	14.8
Chernozem				
NK	0.84	—	—	—
NK + 10 mg. P_2O_5	0.72	4.82	15.0	13.8
NK + 100 mg. P_2O_5	3.00	11.77	25.0	13.3
NK + 1000 mg. P_2O_5	9.85	6.96	142.0	24.3
Sierozem				
NK	0.42	—	—	—
NK + 10 mg. P_2O_5	0.48	1.31	36.3	35.2
NK + 100 mg. P_2O_5	1.36	4.12	30.3	19.2
NK + 1000 mg. P_2O_5	3.91	3.29	119.0	7.7
Krasnozem				
NK	0.43	—	—	—
NK + 10 mg. P_2O_5	0.38	0.05	763	761
NK + 100 mg. P_2O_5	0.41	0.175	234	220
NK + 1000 mg. P_2O_5	2.56	1.49	172	29.1

The content of phosphates in the crop of this experiment depends on the amount of fertilizer applied. The coefficient of utilization of labelled phosphorus changes significantly depending on the amount of labelled fertilizers, i.e. the coefficient of utilization of labelled phosphorus shows the utilization of the fertilizer phosphates, and not of soil phosphates. The coefficient of utilization of labelled phosphorus shows the utilization of soil phosphates when applications of labelled fertilizers are made in minimal quantities which can react fully with the soil and do not affect the phosphorus nutrition of the plants. Lower utilization coefficients for the 10 mg. quantity of P_2O_5 per pot are obtained as a consequence of the strong adsorption of this application by the soil; for the 1000 mg. quantity of P_2O_5 the lower utilization coefficients demonstrate that only a small part of this application is assimilated by the plants. The greatest utilization coefficient at an application of 100 mg. shows that this application of phosphate is used most fully by the plants. In acid soils, which fix phosphates, the utilization coefficient increases with a very high application of P_2O_5. The reserve of available phosphates, calculated by the different recoveries of P_2O_5 in the crop, and by the various utilization coefficients, also is varying and does not correctly describe the reserve of soil phosphates.

At an application of 1000 mg. of P_2O_5 per pot, the phosphate reserve in soils is created at the expense of the fertilizers, and the soil phosphate reserve determined by taking the difference is, of course, entirely inaccurate.

Facts about the reserve of soil phosphates at applications of 10 and 100 mg. of P_2O_5 are more trustworthy. They testify to the smaller utilization of soil phosphates when large applications of P_2O_5 are made; as a result higher values for the size of the reserve of available soil phosphates are obtained.

Conclusions

1. The application of the radioactive isotope P^{32} in pot experiments permits the calculation of the total available soil phosphates and the degree of their mobility.

The utilization coefficient of labelled phosphorus proves to be sufficiently constant for the same soil, regardless of its dilution by sand.

The total available phosphates in the soil, determined with the aid of the radioactive isotope, varies with the quantity of soil taken for the experiment; consequently, it characterizes with sufficient accuracy the actual amount of the reserve of available phosphates in soils.

2. To characterize the phosphate condition of a soil one measure of the soil's reserve of available phosphates is not enough; it is also necessary to calculate the utilization coefficient of labelled phosphates.

3. When labelled phosphorus is applied with a minimum amount of carrier, its intake characterizes the utilization of soil phosphates, their mobility and availability to plants. When a large application of labelled phosphorus is made, its intake does not characterize the utilization of soil phosphates, since the fertilizer influences plant intake of soil phosphates proper.

4. When there is a large reserve of phosphates, the degree of utilization by plants can be quite low (experiment on krasnozem). On the other hand, when there is a small reserve, its degree of utilization may be high (experiment on sierozem).

5. When there is an even distribution in the soil, the application of small amounts of phosphorus fertilizers to carbonate, limed and neutral soils is possible, since under these conditions phosphates are well utilized by the plants. In acid soils the plants will be well provided with phosphorus when there is an even application only if large amounts of fertilizer are used.

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Chronicles

VLADIVOSTOK SECTION ALL-UNION SOCIETY OF SOIL SCIENTISTS

G. I. Ivanov

The Vladivostok Section of the All-Union Society of Soil Scientists was organized in 1956 and now has 9 members.

The associates of this Society are studying the soil cover of the Far East and the dynamics of soil-forming processes, and also developing agricultural practices suited to local bioclimatic conditions.

B. A. Neunylov (Far Eastern Rice Experiment Station) is supervising the investigations of the dynamics of soil processes in the specific conditions of submerged rice fields of the Maritime Region. A. T. Gritzun (Maritime Experimental Station) is studying the dynamics of phosphorus in soils, the influence of different depths of plowing on the hydrophysical properties of soil, and the action of fertilizers in various soil conditions of the Maritime region.

A. I. Kachiyani (Far Eastern Institute for the Scientific Study of Agriculture) carried out an economic survey of reclaimable virgin soils of the Khabarov district.

The laboratory of soil science of the Far Eastern affiliate, Academy of Sciences, USSR, is studying the basic geographical patterns of soils distribution in the Far East and is demonstrating the specific characteristics of the soils of the Khankai foreland plain. During recent years, studies have been done on the mountain-forest soils of Sikhote-Alin, the Ussuri River valley, southern Kamchatka, the upper reaches of the Zea River (G. I. Ivanov); the southern part of the Jewish Autonomous Region (A. V. Druzin), the dynamics and fractional humus content of the soils of the Maritime region (N. V. Khavkina), and the mineral content of the soils of the Khankai foreland plain (A. P. Moskayev).

The Far Eastern Branch, Academy of Sciences, USSR, together with the Far Eastern Scientific Research Institute of Agriculture and with the participation of experimental agricultural establishments, is leading work on the compilation of a 1:500,000 soil map of the Maritime district, a 1:200,000 soil map of the basic agricultural regions of the district, and a 2 to 2½-page explanatory note.

In July 1957, in N. Santakhez, a scientific conference of the Section was held, at which a preliminary working classification of Maritime Region soils was developed. At the time of the conference a field trip was conducted making it possible to consider a number of problems directly in the field.

A group of soil scientists of the Vladivostok section (Rosgiprovodkhoz[1]) is carrying out small-scale mapping of swampy soils with a view to their improvement for agricultural reclamation.

It has been planned to hold a scientific meeting in 1958 at which the results of soil studies in the Far East will be presented and basic problems for further studies will be considered.

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[1] ROSGIPROVODKHOZ = Respublikanskiy gosudarstvennyy institut po proyektirovaniyu vodokhozyaistvennogo i meliorativnogo stroitel'stva, Republic State Institute for the Design and Planning of Water Resources and Reclamation Development—Translator.

KAZAKHSTAN SECTION ALL-UNION SOCIETY OF SOIL SCIENTISTS

M. I. Rubinshtein

On March 19, 1957, the first organizational meeting was held of members of the Kazakhstan section of the All-Union Society of Soil Scientists. Those present elected a Board of Governors for the section and an Inspection Committee. Elected chairman was Corresponding Member of the Academy of Sciences, Kazakh S.S.R., Prof. A. I. Bezsonov; as Vice-Chairman, V. M. Borovskiy, D.Sc.; as Secretary, M. I. Rubinshtein, M.S.

The Board approved a plan of work and resolved to create 14 sections in the districts of the Republic. The question of deficiencies in the conduct of soil studies in the Ministry of Agriculture, Kazakh S.S.R., was considered and discussed.

The governors transmitted to the Central Committee of the Communist Party of the Soviet Union in Kazakhstan and to the Ministry of Agriculture of the Kazakh S.S.R. measures directed at insuring soil projects by proper guidance, supervision by scientific institutions, carrying out sound analyses, and the intensification of scientific-methodological and general advisory help on the part of the Institute of Soil Science, Academy of Sciences, Kazakh S.S.R.

Measures have already been undertaken by the Ministry of Agriculture which are designed to improve the status of soil studies in the Republic. In particular, in the Reclamation Administration of the Ministry, the office of station soil scientist was approved and funds were released for the organization of a laboratory.

In 1957 there were two general meetings of the members of the Kazakhstan Section of the Society of Soil Scientists. At the first of these, reports were heard from associates of the Institute of Soil Science, Academy of Sciences, Kazakh S.S.R. (U. U. Uspanov, A. A. Sokolov, K. Sh. Faizov) on the soils of China, with demonstrations of soil samples, monoliths, and a soil map of China. The reports aroused great interest by the audience.

At a conference dedicated to the 40th anniversary of the October Socialist Revolution, the following reports were heard: 1. Forty years of soil science in Kazakhstan (Director of the Institute of Soil Science, Academy of Sciences, Kazakh S.S.R., U. U. Uspanov). 2. Land resources of Kazakhstan and their agronomic evaluation (S. P. Matusevich, M.S.Agr.). 3. Soils of Altai in the Kazakhstan area (A. A. Sokolev, M.S.). 4. History of soil research in Kazakhstan (D. M. Storozhenko, M.S.). 5. Principles of classification of the soils of Kazakhstan (Prof. A. I. Bezsonov). 6. Results of soil microbiological studies in Kazakhstan (Z. F. Teplyakova, M.S.). It was resolved to hold the second conference of Kazakh soil scientists and agricultural specialists of the Republic in March, 1958. At the conference it is proposed to hear reports on the results of the work of the Esil'sk Station for the study of the fertility of the virgin and idle lands of the Akmolinsk district; from the Dzhanibek Station, Academy of Sciences, USSR, on the reclamation of solonetz complexes of the lowlands of the Caspian foreland; from the Ministry of Agriculture on the organization work on the small-scale mapping of soils; from the workers of the Soil Institute of the Academy of Sciences of the Kazakh S.S.R. on the soils of Central Kazakhstan and Altai; on the problem of the reclamation of the lower reaches of the Ilya River, and so forth.

The Board of Governors of the section intends to conduct courses to raise the qualification of soil scientists working in the reclamation administrations at district level.

ACTIVITIES OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS OF THE USSR DURING 1957

N. A. Razorënova

In 1957 the activity of the All-Union Society of Soil Scientists of the USSR was directed to the further organizational consolidation of previously established branches and sections and the establishment of new ones. Together with this, scientific and science-organization work was conducted by the permanent committees of the Society in Moscow and by the local Affiliates and Branches. Considerable attention was given to preparations for calling a congress of delegates of the All-Union Society of Soil Scientists. The connection with the International Society of Soil Scientists was strengthened and expanded.

At the present time, 15 affiliates of the Society in the Union Republics and 30 branches in the regions and cities of the Russian Soviet Federated Socialist Republic have been organized and have begun to function.

As of January 1, 1958, the All-Union Society of Soil Scientists unites more than 2000 soil scientists and agronomists; of these, 782 members work in scientific establishments; 682 in institutions of higher learning; 526 in Ministries of Agriculture of the USSR, and of Union Republics, regions, Agricultural Administrations, planning institutes; and 13 members are pensioners.

A series of conferences was held during the year by the Organizational Committee of the All-Union Society of Soil Scientists, in which organizational and science-organization problems were resolved; these included the consideration of working plans by the permanent committees, discussion of their activities, and so forth.

In October, 1957, a jubilee scientific session was held jointly by the Soil Institute, Academy of Sciences, USSR, and the House of Scientists; it was devoted to the fortieth anniversary of the Great October Socialist Revolution. At this celebration papers were presented by: Academician I. V. Tyurin, "Achievements of Soviet soil science in the past 40 years"; Academician of the V. I. Lenin All-Union Academy of Agricultural Sciences O. K. Kedrov-Zikhman, "Forty years of Soviet agrochemistry"; Academician of the V. I. Lenin All-Union Academy of Agricultural Sciences V. M. Klechkovsky, "Some problems of 'isotopic' agrochemistry"; I. N. Skrynnikova, M.S., "Present soil processes in the southern part of the peat-podzolic zone"; N. N. Rozov, M.S., "Development of the doctrine of soil zonality"; D. V. Fedorovsky, M.S., "The intake of water and nutrients in plants as a function of soil moisture and salinity."

The scientific activity of the Organizational Committee is being carried out within the permanently active Seventh Commission of the All-Union Society of Soil Scientists.

Thirty sessions of the Commissions were held in 1957. Work was conducted most successfully by the Fifth and Sixth Commission, with subcommissions on the control of soil and swamp erosion. At the sessions reports were presented by workers of the Soil Institute, Academy of Sciences, USSR, the Institute of Geography, Academy of Sciences, USSR, the Moscow State University, the All-Union Institute of Fertilizers and Agricultural Soil Science, and members of certain branches of the All-Union Society of Soil Scientists; in particular, at the session on soil improvement a communication was read by the Chairman of the Altai Branch of the All-Union Society of Soil Scientists, Professor N. V. Orlovsky, on the subject "Utilization and methods of improvement of solonetzes in regions of reclamation of virgin lands."

The First Commission developed a glossary project on soil physics, which has been distributed to all Affiliates and Branches of the Society for consideration. In addition, in the Third, Fifth, and Sixth Commissions, communications were read on soil studies in a number of countries and on the work of foreign Societies of Soil Scientists by Academician I. V. Tyurin, Professor E. N. Ivanova, S. A. Shuvalov, M.S., corresponding member of the Academy of Sciences, USSR, E. N. Mishustin, and D. A. Armand, D.Sc. (Geog.).

The activities of the Affiliates and Branches of the Society were quite varied; they were devoted to increasing the scientific knowledge of their members, to propaganda for knowledge about soil and to rendering scientific aid to production.

At meetings and conferences conducted by the Affiliates and Branches, reports and communications were heard on the most pressing questions of soil science and agronomy, as applied to local conditions. Thus, for example, in the Bashkir, Voronezh, and a number of other Branches, the greatest number of reports were devoted to problems of establishing agricultural soil regions and to the control of soil erosion; the Gruzinian Affiliate devoted a great deal of attention to irrigation problems and the Om and Altai Branches are dealing with the problems of the genesis and improvement of solonetzes, and so forth.

In the second half of 1957 the Affiliates and Branches of the Society carried out a good deal of work in choosing reports for the forthcoming Congress of soil scientists.

The Affiliates and Branches have assisted agricultural workers and soil scientists by holding systematic consultations, often in the field, by giving lectures, by participating in courses, by radio appearances, and so forth.

Especially successful in carrying on this work were the Kazakh, Leningrad, Latvian, and Northern Caucasus Affiliates, and the Alta Bashkir, Voronezh, Komi ASSR, Dagestan, Ku byshev, and Mariysk Branches.

The participation of soil scientists of th USSR at the Sixth International Congress o Soil Scientists (Paris, 1956) contributed to th consolidation of professional relations with th International Union of Soil Scientists and th Societies of individual countries.

In 1957 the All-Union Society of Soil Scientist took part in setting up the working plan for th Fifth Commission of the International Societ of Soil Scientists.

In 1957, members of the All-Union Society o Soil Scientists took part in meetings and excursions of the German Society of Soil Scientist (Academician I. V. Tyurin and correspondin member of the Academy of Sciences, USSR, V. A Kovda), the Polish Society of Soil Scientist (Professor E. N. Ivanova and N. A. Nogina M.S.), and the Japanese Society of Soil Scientist (Academician I. P. Gerasimov). Correspondin members of the Academy of Sciences, USSR E. N. Mishustin and A. A. Imshenetskiy participated in the International Symposium o Methods of Microbiological Soil Research hel in June, 1957, in Belgium.

ACTIVITIES OF COMMISSIONS OF THE INTERNATIONAL SOCIETY OF SOIL SCIENTISTS AND OF SOCIETIES OF SOIL SCIENTISTS OF VARIOUS COUNTRIES

A. A. Yerokhina

THE organizational committee of the All-Union Society of Soil Scientists of the USSR has received No. 11, 1957, of the Bulletin of the International Society of Soil Scientists—the organ of the Council of the International Society of Soil Scientists.

The Bulletin contains information on the activities of the Commissions of the International Society of Soil Scientists planned for 1958 and communications on the work of the Societies of Soil Scientists in various countries.

Commission I (Soil Physics). A meeting was held in Paris Oct. 1, 1956, concurrently with the Sixth International Congress of Soil Scientists, at which the question of methods for determining the stability of the structure of soils was considered. In connection with the decision adopted on the exchange of experience among countries on applicable methods, the commission requests that information be given on the following questions: 1) What methods are employed or determining the stability of soil structure with reference to the soils of the tropics or of he temperate zone); 2) What macroscopic methods are used for determining structure (for given purposes).

Commission III (Soil Biology). In June, 1957, n Louvain (Belgium) a Colloquium was held on methods of microbiological research, at which 0 representatives from 13 countries participated. In accordance with the resolution of the Colloquium, an international inquiry on certain pecial methods of research is contemplated. A questionnaire is being sent out on application to Prof. Pochon, President of the IIIrd Commission, Pasteur Institute, Paris, France. The results of he inquiry will be reported at the Seventh International Congress of Soil Scientists.

A Committee on Soil Fauna has been set up in accordance with the rules of the Society. A colloquium of this committee, devoted to methods for the study of soil fauna, was held at the Rothamsted Experimental Station (Harpenden, Hertfordshire, England) from July 10 to 14, 1958. It is concerned with a preliminary work program and the organization of the committee.

Commission II (Soil Chemistry) and Commission IV (Soil Fertility). A joint Congress of the IInd and IVth Commissions of the Society is being held at Hamburg in the period from August 25 to 30, 1958. A schedule of the work of the Congress and its general organization is published. Among the individual reports are included the following: (1) Types of soil and influence of fertilizers—Prof. Tyurin (Moscow); (2) The role of growth substances produced in the soil—Prof. Flaig (Braunschweig); (3) The distribution of ions in the system of soil solutions—soil-adsorbing complexes—Prof. Shuffelen and Dr. Bolt (Vageningen); (4) The role of isotopes in investigations of soils and of the soil-plant system—Dr. Russel (Oxford).

Commission V—Genesis, classification, and cartography of soils. After the Sixth International Congress of Soil Scientists the directors of the Fifth Commission decided to prepare a project on the international classification of soils for the Seventh International Congress. In connection with this, a plan was set up and coordinated with the national committees for the activity of Fifth Commission in the period between the Sixth and Seventh International Congresses of Soil Scientists. The work plan contemplates setting up a project for the classification of the soils of Europe by the united endeavours of European and Asiatic countries.

Commission VI (Soil Technology). In 1957 it was proposed to hold a special conference of Sixth Commission in Vienna, but the meeting was postponed to 1958. In accordance with the wish of the Danish colleagues, it is proposed to devote the conference to problems of "sprinkler irrigation" and its meeting is planned to be held in Copenhagen in the period from June 30 to July 4, 1958.

In the Bulletin, brief information is also included on the activities of the Societies of Soil Scientists in a number of foreign countries.

The *Belgian Society of Soil Science* (founded in 1950) has now published five annual Bulletins under the title "Soil Science," in which scientific material is published.

The *Canadian Society of Soil Science* has been in existence for five years. The Bulletin gives notice of the third annual conference of the Society in 1957 in Vancouver, British Columbia, at which 25 papers were presented, and at which the council of the society, published in the Bulletin, was also elected. A periodical organ of The Society's periodical, "Canadian Journal of Soil Science," is planned for publication twice a year.

The *Italian Society of Soil Science*. On May 7 and 8, 1957, at Pisa, a symposium on clay was held. The materials of the symposium will be published in the Journal "Agrochimia."

The *Japanese Society of Soil Science and Fertilizers*. The number of members of the Society, according to the Bulletin, has now increased to 1992 persons. The annual meeting was held in Tokyo April 7–9; 245 papers were presented.

The quarterly journal "Soil and Plant Food" appeared initially in May, 1955. It is printed in European languages, chiefly English.

The *New Zealand Society of Soil Science*. The Bulletin reports the second conference of the New Zealand Society of Soil Science, which was held in November, 1956, at Lincoln College Reports were devoted to three problems: 1. The soils and productivity of pastures in Canterborn; 2. Soil problems of South Island; and 3. Soil moisture. Also heard were an appeal of the President "The Call to Soil Science" (Grimlett); a report on "Soil Science in the Soviet Union" (Taylor) and "Some Aspects of Molybdenum" (Askew). The reports of the conference were published in its Proceedings. The members of the Council of the Society, elected for the period 1956–1958, are given.

The *Scandinavian Regional Group*. It is announced that the representative for the 40 Scandinavian members of the International Society of Soil Scientists is Prof. Dr. Lag.

The *All-Union Society of Soil Scientists of the USSR*. The Bulletin announces the members of the Organization Committee of the Society, its membership, and the creation and composition of Seventh Commission.

In addition, announcement is made of the Ninth International Botanical Congress, which is planned for August 19 to 29, 1959, in Montreal, Canada.

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